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RESHAPING THE GRADUATE EDUCATION OF SCIENTISTS AND ENGINEERS: NAS's COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY REPORT

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Reshaping the Graduate Education of...

HEARING

BEFORE THE

SUBCOMMITTEE ON BASIC RESEARCH

OF THE

COMMITTEE ON SCIENCE
U.S. HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTH CONGRESS

FIRST SESSION

JULY 13, 1995

[No. 19]

Printed for the use of the Committee on Science

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RESHAPING THE GRADUATE EDUCATION OF SCIENTISTS AND ENGINEERS: NATIONAL ACADEMY OF SCIENCES' COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY REPORT

THURSDAY, JULY 13, 1995

U.S. HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE,
SUBCOMMITTEE ON BASIC RESEARCH,
Washington, D. C.

The Subcommittee met at 9:40 a.m. in Room 2318 of the Rayburn House Office Building, the Honorable Steven H. Schiff, Chairman of the Subcommittee, presiding.

Mr. SCHIFF. Good morning, everybody. I would like to call the Subcommittee to order.

I have a brief opening statement I would like to read into the record, and I will recognize our ranking member, Mr. Geren of Texas, for any opening statements he might like to make.

We are here today to examine a report from the National Academy of Sciences Committee on Science Engineering and Public Policy, entitled "Reshaping Graduate Education of Scientists and Engineers." This report looks at the process by which scientists and engineers are educated and makes recommendations for preparing students for future success.

I strongly believe that science and technological advances will eventually solve most of this country's social, economic, and environmental problems. I became a member of the Science Committee to ensure that the Federal Government's role in science is both adequate and beneficial.

That said, I am pleased that the Subcommittee has this opportunity to examine the process of graduate education because of its critical link to ensuring that our Nation is able to meet these challenges with high technologies and advanced scientific solutions.

The Ph.D.-level educated scientist and engineer plays a central role in the prosperity, security, and competitiveness of our Nation. Their successes are the Nation's successes. The COSEPUP, which is the acronym for the committee report, urges that modifications be made to America's system of graduate education in order to ensure the future success of these individuals. This should be done not only because scientists and engineers will be employed to help solve the major social and economic concerns that we're facing, but also because today's Ph.D. candidate is tomorrow's educator.

The report examines the graduate education in the context of the end of the Cold War era and a change in the economy. The report found that an increasing number of scientists and engineers are finding employment outside the traditional places of employment, which were universities and government laboratories.

This is the result of two phenomena—an increase in the number of Ph.D.s produced, and a reduction in Federal and corporate funding of basic research. While the report did not find high unemployment among Ph.D.s, it did find that recent graduates are unemployed for longer periods of time after graduation, that students are taking longer to receive their degrees, and the number of Ph.D.s who are in postdoctoral positions for longer periods of time is increasing.

In addition, the report predicts a continuing decline in the traditional employment opportunities in academia and makes several recommendations for helping students meet this reality. Among the committee's recommendations is that the United States doctoral-granting universities should do a better job in preparing students for careers by increasing flexibility and versatility in the degree program and providing more relevant career counseling.

The Subcommittee will carefully consider what role that financial support mechanism, including Federal support, should play in fostering a broader graduate education for scientists and engineers.

The report recommends that students be provided with more complete career employment information in order to make good choices about their education. The Subcommittee will explore ways that the students can be assured that they will receive adequate, relevant, and timely guidance throughout their graduate education.

I think it is important to note that although the report did not conclude that there is an oversupply of Ph.D.s or a need to limit the production of Ph.D.s, other recently released studies have found this to be a problem.

I am happy that we have a diverse panel of witnesses who can address this sensitive issue in more detail, as there are some in the scientific community who believe that overproduction of Ph.D.s is having a detrimental effect on recent graduates and young scientists.

Before recognizing the witnesses, I would like to turn to my ranking Democratic colleague on the Subcommittee, Mr. Geren, and ask if he has any opening statement.

[The prepared statement of Mr. Schiff follows:]

CHAIRMAN SCHIFF'S OPENING STATEMENT

JULY 13, 1995

HEARING ON GRADUATE EDUCATION

WE ARE HERE TODAY TO EXAMINE A REPORT FROM THE NATIONAL ACADEMY OF SCIENCES' COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY (COSEPUP) ENTITLED "RESHAPING THE GRADUATE EDUCATION OF SCIENTISTS AND ENGINEERS." THIS REPORT LOOKS AT THE PROCESS BY WHICH SCIENTIST AND ENGINEERS ARE EDUCATED AND MAKES RECOMMENDATIONS FOR PREPARING STUDENTS FOR FUTURE SUCCESS.

BECAUSE I STRONGLY BELIEVE THAT SCIENTIFIC AND TECHNOLOGICAL ADVANCES WILL EVENTUALLY SOLVE MOST OF THIS COUNTRY'S SOCIAL, ECONOMIC, AND ENVIRONMENTAL PROBLEMS, I BECAME A MEMBER OF THE SCIENCE COMMITTEE TO ENSURE THAT THE FEDERAL GOVERNMENT ROLE IN SCIENCE IS BOTH ADEQUATE AND BENEFICIAL. THAT SAID, I AM PLEASED THAT THE SUBCOMMITTEE HAS THIS OPPORTUNITY TO EXAMINE THE PROCESS OF GRADUATE EDUCATION BECAUSE OF ITS CRITICAL LINK TO ENSURING THAT OUR NATION IS ABLE MEET THESE CHALLENGES WITH HIGH TECHNOLOGIES AND ADVANCED SCIENTIFIC SOLUTIONS.

THE PHD-LEVEL EDUCATED SCIENTIST AND ENGINEER PLAYS A CENTRAL ROLE IN THE PROSPERITY, SECURITY, AND COMPETITIVENESS OF OUR NATION. THEIR SUCCESSES ARE THE NATION'S SUCCESSES. THE COSEPUP REPORT URGES THAT MODIFICATIONS BE MADE TO AMERICA'S SYSTEM OF GRADUATE EDUCATION IN ORDER TO ENSURE THE FUTURE SUCCESS OF THESE INDIVIDUALS. THIS SHOULD BE DONE NOT ONLY BECAUSE SCIENTISTS AND ENGINEERS WILL BE EMPLOYED TO HELP SOLVE THE MAJOR SOCIAL AND ECONOMIC CONCERNS WE WILL FACE, BUT ALSO BECAUSE TODAY'S PHD CANDIDATE IS TOMORROW'S EDUCATOR.

The COSEPUP REPORT EXAMINES GRADUATE EDUCATION IN THE CONTEXT OF THE END OF THE COLD WAR ERA AND A CHANGING ECONOMY. THE REPORT FOUND THAT AN INCREASING NUMBER OF SCIENTISTS AND ENGINEERS ARE FINDING EMPLOYMENT OUTSIDE THE TRADITIONAL PLACES OF EMPLOYMENT (UNIVERSITIES AND GOVERNMENT LABORATORIES.) THIS IS THE RESULT OF TWO PHENOMENA: AN INCREASE IN THE NUMBER OF PHDS PRODUCED; AND A REDUCTION IN FEDERAL AND CORPORATE FUNDING OF

BASIC RESEARCH.

WHILE THE REPORT DID NOT FIND HIGH UNEMPLOYMENT AMONG PHDS, THEY DID FIND THAT RECENT GRADUATES ARE UNEMPLOYED FOR LONGER PERIODS AFTER GRADUATION, THAT STUDENTS ARE TAKING LONGER TO RECEIVE THEIR DEGREES, AND THAT THE NUMBER OF PHDS WHO ARE IN POSTDOCTORAL POSITIONS FOR LONGER PERIODS OF TIME HAS IS INCREASING. IN ADDITION, THE REPORT PREDICTS CONTINUED DECLINE IN TRADITIONAL EMPLOYMENT OPPORTUNITIES IN ACADEME AND MAKES SEVERAL RECOMMENDATIONS FOR HELPING STUDENTS MEET THIS REALITY.

AMONG THE COMMITTEE'S RECOMMENDATIONS IS THAT U.S. DOCTORAL GRANTING UNIVERSITIES SHOULD DO A BETTER JOB IN PREPARING STUDENTS FOR CAREERS BY INCREASING FLEXIBILITY AND VERSATILITY IN THE DEGREE PROGRAM AND BY PROVIDING MORE RELEVANT CAREER COUNSELING. THE SUBCOMMITTEE WILL CAREFULLY CONSIDER WHAT ROLE THAT FINANCIAL SUPPORT MECHANISMS, INCLUDING FEDERAL SUPPORT, SHOULD PLAY IN FOSTERING A BROADER GRADUATE

EDUCATION FOR SCIENTISTS AND ENGINEERS.

THE REPORT RECOMMENDS THAT STUDENTS BE PROVIDED WITH MORE COMPLETE CAREER AND EMPLOYMENT INFORMATION IN ORDER TO MAKE GOOD CHOICES ABOUT THEIR EDUCATION. THE SUBCOMMITTEE WILL EXPLORE WAYS THAT STUDENTS CAN BE ASSURED THAT THEY WILL RECEIVE ADEQUATE, RELEVANT, AND TIMELY GUIDANCE THROUGHOUT THEIR GRADUATE EDUCATION.

I THINK THAT IT IS IMPORTANT TO NOTE THAT ALTHOUGH THE REPORT DID NOT CONCLUDE THAT THERE IS AN OVERSUPPLY OF PHDS OR A NEED TO LIMIT THE PRODUCTION OF PHDS, OTHER RECENTLY RELEASED STUDIES HAVE FOUND THIS TO BE A PROBLEM. I AM HAPPY THAT WE HAVE A DIVERSE PANEL OF WITNESSES THAT CAN ADDRESS THIS SENSITIVE ISSUE IN MORE DETAIL AS THERE ARE SOME IN THE SCIENTIFIC COMMUNITY WHO BELIEVE THAT OVERPRODUCTION OF PHDS IS HAVING DETRIMENTAL EFFECTS ON RECENT GRADUATES AND YOUNG SCIENTISTS.

Mr. GEREN. Thank you, Mr. Chairman. I do have a brief opening statement.

I want to welcome our witnesses and guests to our hearing today. Mr. Chairman, I believe that most of those in attendance here this morning would agree that graduate education in science and engineering is a major strength of our national education system. The excellence of our graduate education is recognized throughout the world and is reflected in the large number of international students who seek entrance to U.S. graduate schools.

In a very real way, graduate education in science and engineering underpins the R&D enterprise of our Nation. Federal support for university-based research has had a significant influence on graduate education because of the close linkage between research and education in American universities. This linkage is generally regarded as an important reason for the strength of the U.S. graduate education system.

At the same time, it is appropriate to consider whether the scale of the Federal research investment at universities may have distorted the balance between research and education. The prestige of an academic institution is tied to the amount of Federal research funding received. Faculty members' track record of success in obtaining research grants is a major factor in promotion and tenure decisions. Graduate students provide much of the labor force essential for carrying out the research.

Today, most Federal support for graduate students is in the form of graduate research assistantships funded by research grants to faculty members. Under the current system, then, are the long-term educational interests of graduate students given adequate emphasis? That is a question that must be addressed.

The recent report from the National Academy of Sciences on graduate education, which we shall hear more about this morning, suggests that improvements are needed to ensure that graduate students are prepared to succeed in the evolving science and technology workforce, a workforce in which most new Ph.D.s will pursue careers outside of academia.

I look forward to a review of the Academy's findings during this hearing, and I am very interested in the reactions and suggestions of our witnesses regarding these findings. Changes to the graduate education system are rightly the principal responsibility of the universities and their faculties, but, of course, the Federal agencies that now provide significant graduate student support also have a role to play in any reforms that are pursued. I encourage our witnesses to provide the guidance on steps that the government can take to assist us in effecting needed reforms.

Mr. Chairman, I congratulate you for convening this hearing. I am pleased to join you in welcoming our distinguished witnesses and look forward to their testimony.

Mr. SCHIFF. Thank you, Mr. Geren.

I want to again say it is always a pleasure to work with you and your staff and your members. I think between us we help keep the Subcommittee an oasis of nonpartisanship in the seas that surround us, and I would like to continue to do that.

Without objection, every member of the Subcommittee who wishes to enter an opening statement in writing will be allowed to do

so. However, if there is any member of the Subcommittee who really feels a strong desire to make an oral opening statement, I will recognize them.

I just want to say to everybody that I am just expecting a lot of votes today. Therefore, the sooner we can move along, the better for everybody. But I would not preclude anybody from speaking. I am not quite there yet, but that is a warning.

[Laughter.]

Mrs. MORELLA. Mr. Chairman, thank you. I will ask that an opening statement be included in the record.

[The prepared statement of Mrs. Morella follows:]

CONSTANCE A. MORELLA

SST

RE: ENGINEERING EDUCATION

JULY 13, 1995

MR. CHAIRMAN, I AM PLEASED TO WELCOME OUR DISTINGUISHED PANEL HERE TODAY TO DISCUSS THE GRADUATE EDUCATION OF OUR NATION'S ENGINEERS AND SCIENTISTS. TODAY'S HEARING WILL GIVE US A FIRST HAND ACCOUNT OF THE CHALLENGES FACING STUDENTS AND RECENT GRADUATES IN THIS FIELD.

PHD-LEVEL EDUCATED ENGINEERS AND SCIENTISTS ARE INTEGRAL TO THE FUTURE SUCCESS OF OUR NATION AS WE MOVE INTO THE TWENTY-FIRST CENTURY. THEY DO NOT ONLY ACT AS PROFESSIONALS, BUT MANY ALSO TAKE ON THE TASK OF EDUCATING FUTURE MEMBERS OF THE SCIENCE COMMUNITY.

I look forward to learning more about

THE NATIONAL ACADEMY OF SCIENCES' COMMITTEE ON SCIENCE, ENGINEERING AND PUBLIC POLICY RECENTLY RELEASED A REPORT COVERING THE CURRENT EMPLOYMENT SCENARIO AND SUGGESTED MODIFICATIONS. FLEXIBILITY IN THE DEGREE

PROGRAM AND POSSIBLE LIMITED ENROLLMENT ARE BOTH PROBABLE SOLUTIONS TO THE LENGTHINESS OF THE CURRENT EMPLYMENT PROCESS.

I LOOK FORWARD TO HEARING THE TESTIMONY OF OUR WITNESSES.

THANK YOU, MR. CHAIRMAN.

Mrs. MORELLA. I just want to thank you for holding this hearing. We have an incredibly distinguished group of panelists who appear before us. I simply must acknowledge not only Dr. Lane but Dr. Varmus, who is the director of the National Institutes of Health, which, as you know, is in my district. Also, on panel two, Dr. Kevin Aylesworth is from Gaithersburg, Maryland, which is also in Maryland's Eighth Congressional District. I commend you on your outstanding selection of panelists to appear before the Committee.

Mr. SCHIFF. Thank you. You say that NIH is in your district. You had better keep a close watch on that throughout the hearing, the contest between States later. On this side, Congressman Hastings?

Mr. HASTINGS. Mr. Chairman, you have already indicated all our statements will be placed in the record. I appreciate it. I have one interest that Dr. Griffiths is going to address, and that is time to degree. I note that that is an interest of his. But I think you are to be congratulated on holding this hearing, Mr. Chairman.

[The prepared statement of Mr. Hastings follows:]

PREPARED STATEMENT OF HON. ALCEE L. HASTINGS

I thank the Chair and would also like to congratulate him for having the foresight to hold hearings on this important issue.

Congress, as a whole, is often called upon to look into a crystal ball and find answers to questions that have not been asked. I find that expectation to be especially true with the Science Committee and its Basic Research Subcommittee. The decisions that we make not only affect this country's leadership in the realm of basic and applied science, but they also affect this country's economic power in a growing world market.

Today we are faced with the serious question of whether or not there has been an overproduction of PhD's and whether or not our educational institutions are training our future scientists in a manner that will make them relevant in the job market.

One method mentioned of handling the potential problem of too many PhD's is limiting international enrollment in PhD programs. This is not a solution with which I agree. This country, and especially its educational system, must not encourage xenophobia. I have often said that one of Amnerica's greatest assets is its diversity. This is no less true when discussing diversity in education.

Short of such unreasonable measures, I look forward to an in depth discussion of the issues at hand and as well an in depth analysis as how to address them.

Thank you.

Mr. SCHIFF. Thank you, Mr. Hastings.

Mr. Ehlers?

Mr. EHLERS. Thank you, Mr. Chairman.

Just very briefly. First of all, an apology to you and members of the panel. I have a bill up in the Judiciary Committee at 10 o'clock, so I have to step out for that, but I will try to return.

The other comment I would make is just to register at the beginning, and perhaps the panelists want to explicitly address this concern, I remain extremely skeptical about any plans to in some way control the supply of Ph.D. scientists that are permitted to enter and to leave graduate school.

This goes back to my experience as a professor. I recall some years ago the word was out that there were enough engineers. Engineers were having a tough time finding jobs. The word spread throughout the community. Engineering enrollment at the school at which I taught dropped dramatically. Many of them switched to business and a few other professions. Four years later, when these students graduated, there was a great demand for engineers, partially because the low enrollment in that field.

There was an oversupply in business administration, and all these students came around and said, "Why didn't you tell me to go into engineering?"

To somehow think that we have the knowledge and perspective to adequately judge what the future needs are of the Nation in a particular economic area I think is a gross act of egoism and should be avoided.

I would also comment that many of my friends that graduated with me and got Ph.D.s in physics have entered other fields. One is an extremely successful stockbroker. I fell away, actually, into Congress.

[Laughter.]

Mr. EHLERS. But I would say about half of my classmates ended up in fields other than physics. But the analytical skills they learned as physicists have served them very well. Their scientific background has served them very well in the professions they entered, and I happen to think that training in the sciences is a good background for entering any profession. Therefore, I am reluctant to be part of any scheme that limits that enrollment.

Thank you.

Mr. SCHIFF. Thank you.

Mr. Bartlett?

Mr. BARTLETT. Thank you very much.

Having spent the major part of my life as a teacher and researcher in science, I really look forward to this hearing and am very appreciative of the high quality of witnesses that have been called to this hearing. Thank you very much, Mr. Chairman.

Mr. SCHIFF. I want to take a moment to say that there is no shortage of lawyers. I feel especially fortunate to have the two individuals who have actually done hands-on research both on this Subcommittee. Any further requests for opening statements?

[No response.]

Mr. SCHIFF. Seeing none, I would like to welcome Dr. Phillip Griffiths to testify. Dr. Griffiths is the Chair of the Committee on Science, Engineering, and Public Policy of the National Academy of Sciences, which produced the report that is under consideration today, and is also director of the Institute for Advanced Study at Princeton University.

Dr. Griffiths, welcome. As you know, our procedure is, without objection, your written statement will be made a part of the record, and I would welcome you summarizing as you see fit. Then we will proceed to questions.

STATEMENT OF DR. PHILLIP GRIFFITHS, CHAIR, COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY, NATIONAL ACADEMY OF SCIENCES; AND DIRECTOR, INSTITUTE FOR ADVANCED STUDY, PRINCETON, NEW JERSEY

Dr. GRIFFITHS. Thank you, Mr. Chairman. I very much appreciate the opportunity that you and your colleagues have given me to present a statement on this important subject.

In the fall of 1993 the Committee on Science, Engineering, and Public Policy proposed a thorough study of the Nation's graduate education and training systems for scientists and engineers. The purposes of the study were to assess how well the system is able

to support national research and technology goals in the post-Cold War era and to recommend any needed improvements and to recommend new national goals.

In exploring this issue, we have had extended and elaborate discussions with representatives from academe, government, and industry. We have and solicited and gotten formal written responses from graduate students, postdoctorates, traditional and nontraditional employers, researchers, deans, and administrators throughout the country.

One of our findings did not surprise us. Our graduate schools have done such a superb job in educating scientists and engineers that our system has become a model for the world. But we also found that several important assumptions about the careers of scientists and engineers do not hold up under close examination. Let me name just a couple of them.

Myth number one is that most Ph.D.s go on to careers in academe. We all know about the so-called standard career model. Young Ph.D.s find a job where they continue the research they began in graduate school and acquire research assistants of their own. This model is accurate in some cases, but it is not the norm. In fact, more than half of Ph.D.s go to nonacademic jobs, and this proportion has been growing steadily over the last 20 years.

Myth number two is that there is high unemployment among Ph.D.s. This assertion is dramatized in both the popular scientific press, but according to the latest data, unemployment among all scientists and engineers is low, around 1.6 percent in 1993. For new Ph.D.s, the rate has risen to about 2 percent in 1993 from about 1.5 percent during the 1980's. Both figures are far lower than those for professionals and for the labor force as a whole.

Rather, the high unemployment rates of Ph.D.s upon graduation is due instead to delays in employment rather than true unemployment.

Now let me offer a couple of facts. First, while the number of jobs in traditional areas, such as the academic sector and in basic research are decreasing, the number of Ph.D.s employed in business and industry and in applied research and development is increasing.

Second, both the time required to find employment and the time required to earn a doctorate have lengthened in all fields of science and engineering over the last 30 years. In some fields, this increase is more than 30 percent.

Third, and this fact is based largely on interviews and testimony heard by the committee, more new Ph.D.s are entering postdoctoral study, working in temporary research positions, or taking one-year faculty jobs. In other words, the queue is forming for tenure track and other potentially permanent jobs, and the queue seems to be growing longer.

What result do we see when we add these myths and facts together? One is that recent Ph.D.s are finding jobs, but they are finding nonacademic jobs more easily than they are finding academic research positions. They are feeling the pain of unmet expectations.

Another result is that there is something inefficient about the process by which we are educating our Ph.D.s and preparing them

for employment. In part, this inefficiency is caused by large structural changes in the employment landscape, cuts in defense spending, restructuring industries, and slower growth in Federal R&D spending have altered our market for scientists and engineers. And the conduct of science is changing. The organization of science is becoming more flexible as boundaries between fields become more permeable. As a result, scientists place high values on scientists and engineers who can communicate, collaborate, and work across disciplines.

Meanwhile, graduate students still are encouraged to specialize in their own disciplines. This might be appropriate if the only mission of graduate programs were to produce the next generation of academic researchers. But our new Ph.D.s must be prepared to meet broader challenges, including the needs of industrial and technological development, health care, environmental protection, economic growth, pre-college education, and urban decay.

So, how can we modify what is, in many ways, a highly successful system so that it offers greater educational value? How can we produce students who have more career choices and employment options, who can become more valuable to their employers?

Let me offer a summary of our recommendations. We envision the Ph.D. of the future as a different degree from that of the present. It would retain the best aspects of the existing Ph.D. in providing students an independent research experience. At the same time, it would have the different goal of enhancing career options and broadening students' horizons. This goal is reflected already in numerous programs in experiments underway at many universities and colleges.

First, we suggest that graduate programs be more flexible and provide more options for students. In the past, graduate school was seen as a relatively straight and narrow path toward academic employment. Our report suggests that this path should be neither straight nor narrow, but should consist of multiple branching decision points.

Greater versatility can be promoted on two levels. On the academic level, students should be discouraged from overspecializing. Those planning research careers should be grounded in the broad fundamentals of their fields and familiar with several subfields. Such breadth might be much harder to gain after graduation.

On the level of career skills, there is value in experiences that supply skills desired by both academic and nonacademic employers, especially the ability to communicate complex ideas to nonspecialists and the ability to work well in teams.

Off campus, internships in industry or government can lead to additional skills and exposure to authentic job situations.

Let me add that we discussed various alternatives to the traditional degree, including a non-research version that some people have called "Ph.D.-lite." However, we heard consistently from employers that they place extremely high value on the original research experience provided by the Ph.D..

Our second recommendation is that students should receive better career information and guidance. This is an area where we feel students have not been well served. If graduate students are going to make good decisions in planning their academic and professional

careers, they need more up-to-date, accurate, and accessible information.

In our report, the committee recommends the establishment of a national database of information on employment options and trends. This information is intended for both students and faculty advisors, and it should include data on career paths as well as on such topics as graduate programs, financial aid, time to degree, and placement rates. We urge the partners to enhance the quality of the information by tracking the employment experiences of their own graduates.

Additional analysis is needed as well. For example, the National Research Council is currently conducting two independent analyses of the employment patterns and career paths of young doctorates in the fields of life sciences and physical sciences. We believe that greatly improved information and guidance will enhance the ability of the system to self-correct over time and improve the balance of supply and demand.

When the employment situation is poor, better-informed students can pursue options other than the Ph.D.. When the market is expanding, students can move more flexibly and rapidly in the direction of employment demand.

COSEPUP will be conducting two projects itself to inform students, hopefully in conjunction with disciplinary societies. The first project will provide a brief summary of our graduate education report to students and their advisors so they are better informed about graduate education and the employment market for scientists and engineers.

In the second project, COSEPUP will develop an Internet-based student decisionmaking guide so students have advice available to them when they make decisions such as whether or not to attend graduate school, how they should manage their graduate program, and when they evaluate the full range of career options they can pursue.

Third, we believe that time to degree should be tightened. Although we did not make a formal recommendation in the report, the committee feels that both curricula and time to degree can be better controlled. It now takes about eight years to get a Ph.D. in science and engineering, an increase of almost two years since 1962.

While we do need to consider the needs of graduate students who have families and must support themselves, we feel that there can be tightening. Our concern is that students now remain in graduate school longer than necessary, working as research and teaching assistants. For various reasons, arts and sciences faculties have been less disciplined than professional school faculty in tightening their curriculum.

Fourth, we recommend a new class of grants called education/training grants. These grants would be awarded competitively to institutions and departments that propose to improve the versatility of students, strengthen advisory systems, tighten curricula, and so on.

Another goal is to shift the extra work required for a career in basic research into the postdoctoral years. This by itself would help shorten the time to degree.

These grants can also be used to promote certain emerging fields, interdisciplinary programs, industry involvement, and the participation of underrepresented groups.

You will note that we have not, as have others, called for limits on the number of Ph.D.s. Such a step is neither desirable nor practical. There is no effective simple mechanism by which to limit enrollments, and even if there were, it would have little immediate impact.

It is hard to imagine, for example, setting a national quota on the number of Ph.D. mathematicians that would be produced by this country. How would such a limit be set? Who would set this limit? Who would decide which institutions could and could not grant a given number of Ph.D.s? How would it be enforced, and once a limit is set, how long would it be set for? What if the country suddenly needed additional expertise in the area of biotechnology, for example, and the human resources were unavailable?

The graduate education system is a highly decentralized one, and attempts to direct it may have surprising and unintended consequences that could be harmful to the research enterprise as a whole. Therefore, it is better to let the marketplace dictate policy, provide students with the information and education they need to respond to that marketplace, and let academic institutions continue to decide on their own how many students are appropriate for the program and how long it should take students to attain a degree.

I would like to summarize by telling you the top three items where your committee could specifically help support appropriate changes in the graduate education system. Note that none of these changes require additional funding. Rather, they require reallocation of funding currently available.

These actions include encouraging the efforts of NSF, NIH, and other agencies to fund graduate education to, one, adjust support mechanisms to recruit education/training grants to departments and programs. These grants would provide financial incentives for universities to improve the versatility of graduate programs, provide better career information and guidance, and to control the time it takes to attain a degree.

Second, establish a national database designed and managed by the research community on employment options and trends. These databases could provide students and their advisors with more appropriate and timely information.

Third, improve the coverage, timeliness, and analysis of data on the education and employment of scientists and engineers. This analysis should focus on the current employment marketplace for graduate scientists and engineers.

Thank you very much. I would be happy to answer any questions you might have about the report or possible actions the Federal Government could take in this area.

[The prepared statement of Dr. Griffiths follows:]

Phillip A. Griffiths, PhD

Director, Institute for Advanced Study
Princeton, N.J.

and

Chair, Committee on Science, Engineering, and Public Policy (COSEPUP)
National Academy of Sciences
National Academy of Engineering
Institute of Medicine

Testimony on
Reshaping the Graduate Education of Scientists and Engineers

Before
U.S. House of Representatives
Committee on Science
Subcommittee on Basic Science

July 13, 1995

In the fall of 1993, the Committee on Science, Engineering, and Public Policy proposed a thorough study of the nation's graduate education and training system for scientists and engineers. The purposes of the study were to assess how well that system is able to support national research and technology goals in the post-Cold War era, to recommend any needed improvements, and to develop new national goals.

In exploring this issue, we've had extended and lively discussions with representatives of academe, government, and industry. We've met and solicited formal, written responses from graduate students, postdoctorates, traditional and non-traditional employers, researchers, deans, and administrators throughout the country.

One of our findings did not surprise us: Our graduate schools have done such a superb job educating scientists and engineers that our system has become a model for the world. But we also found that several important assumptions about the careers of scientists and engineers do not hold up under close examination. Let me name just a couple of them.

Myth number 1 is that most PhDs go on to careers in academe. We all know about the so-called standard career model: Young PhDs find a job where they continue the research they began in graduate school and acquire research assistants of their own.

This model is accurate in some cases, but it is not the norm. In fact, more than half of PhDs go on to non-academic jobs, and this proportion has been growing steadily over the last 20 years.

Myth number 2 is that there is high unemployment among PhDs. This assertion is dramatized in both the popular and scientific press, but according to the latest data, unemployment among all scientists and engineers is low — around 1.6 percent in 1993. For

new PhDs, the rate has risen to about 2 percent in 1993 from about 1.5 percent during the 1980s. Both figures are far lower than those for professionals, and for the labor force as a whole. Rather, the high unemployment rates of PhDs upon graduation is due instead to delays in employment rather than true unemployment.

Now let me offer a couple of facts. First, while the number of jobs in traditional areas such as the academic sector and in basic research are decreasing, the number of PhDs employed in business and industry and in applied research and development is increasing.

Second, both the time required to find employment and the time required to earn a doctorate have lengthened in all fields of science and engineering over the last 30 years. In some fields this increase is more than 30 percent.

Third, and this fact is based largely on interviews and testimony heard by the committee, more new PhDs are entering postdoctoral study, working in temporary research positions, or taking one-year faculty jobs. In other words, a queue is forming for tenure-track and other potentially permanent jobs, and the queue seems to be growing longer.

What result do we see when we add these myths and facts together? One is that recent PhDs are finding jobs — but they are finding non-academic jobs more easily than they are finding academic research positions. They are feeling the pain of unmet expectations. Another result is that there is something inefficient about the process by which we are educating our PhDs and preparing them for employment.

In part, this inefficiency is caused by large structural changes in the employment landscape. Cuts in defense spending, restructuring in industries, and slower growth in federal R&D spending have altered our market for scientists and engineers.

And the conduct of science is changing. The organization of science is becoming more flexible as the boundaries between fields become more permeable. As a result, employers place high value on scientists and engineers who can communicate, collaborate, and work across disciplines.

Meanwhile, graduate students still are encouraged to specialize in narrow disciplines. This might be appropriate if the only mission of graduate programs were to produce the next generation of academic researchers. But our new PhDs also must be prepared to meet broader challenges including the needs of industrial and technological development, health care, environmental protection, economic growth, pre-college education, and urban decay.

So how can we modify what is in many ways a highly successful system so that it offers greater educational value? How can we produce students who have more career choices and employment options, and who become more versatile and valuable to their employers? Let me offer a summary of our recommendations.

We envision the "PhD of the future" as a different degree from that of the present. It would retain the best aspects of the existing PhD in providing students an independent research experience. At the same time, it would have the different goal of enhancing career options and broadening students' horizons. This goal is reflected already in numerous programs and experiments under way at many universities and colleges.

First, we suggest that graduate programs be more flexible and provide more options for students. In the past, graduate school was seen as a relatively straight and narrow path toward academic employment. Our report suggests that this path should be neither straight nor narrow, but should consist of multiple, branching decision points.

Greater versatility can be promoted on two levels. On the academic level, students should be discouraged from over-specializing. Those planning research careers should be grounded in the broad fundamentals of their fields and be familiar with several subfields. Such breadth might be much harder to gain after graduation.

On the level of career skills, there is value in experiences that supply skills desired by both academic and non-academic employers, especially the ability to communicate complex ideas to non-specialists and the ability to work well in teams. Off-campus internships in industry or government can lead to additional skills and exposure to authentic job situations.

Let me add that we discussed various alternatives to the traditional degree, including a non-research version that some people have called "PhD-lite." However, we heard consistently from employers that they place high value on the original research experience provided by the PhD.

Our second recommendation is that students should receive better career information and guidance. This is an area where we feel students have not been well served. If graduate students are going to make good decisions in planning their academic and professional careers, they need more up-to-date, accurate, and accessible information.

In our report, the committee recommends the establishment of a national data base of information on employment options and trends. This information is intended for both students and faculty advisers, and it should include data on career paths as well as on such topics as graduate programs, financial aid, time to degree, and placement rates. We urge departments to enhance the quality of the information by tracking the employment experiences of their own graduates.

Additional analysis is needed as well. For example, the National Research Council is currently conducting two independent analyses of the employment patterns and career paths of young doctorates in the fields of life sciences and physical sciences.

We believe that greatly improved information and guidance will enhance the ability of the system to self-correct over time and improve the balance of supply and demand. When the employment situation is poor, better informed students can pursue options other than the PhD; when the market is expanding, students can move more flexibly and rapidly in the direction of employment demand.

COSEPUP will be conducting two projects itself to inform students, hopefully in conjunction with disciplinary societies. The first project will provide a brief summary of our graduate education report to students and their advisors so they are better informed about graduate education and the employment market for scientists and engineers. In the second project, COSEPUP will develop a internet-based student decisionmaking guide so students have advice available to them when they make decisions such as whether or not to attend graduate school, how they should manage their graduate program, and when they evaluate the full range of career options they can pursue.

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than necessary, working as research and teaching assistants. For various reasons, arts and sciences faculty have been less disciplined than professional school faculty in tightening their curricula.

Fourth, we recommend a new class of grants called education/training grants. These grants would be awarded competitively to institutions and departments that propose to improve the versatility of students, strengthen advisory systems, tighten curricula, and so on. Another goal is to shift the extra work required for a career in basic research into the postdoctoral years. This by itself would help shorten the time to degree. These grants also can be used to promote certain emerging fields, interdisciplinary programs, industry involvement, and the participation of underrepresented groups.

You will note that we have not, as have others, called for limits on the number of PhDs. Such a step is neither desirable or practical. There is no effective central mechanism by which to limit enrollments and even if there were, it would have little immediate impact. It is hard to imagine, for example, setting a national quota on the number of PhD mathematicians that would be produced by this country. How would such a limit be set? Who would set this limit? Who would decide which institutions could and could not grant a given number of PhDs? How would it be enforced? And, once a limit is set, how long would it be set for? What if the country suddenly needed additional expertise in the area of biotechnology, for example, and the human resources were unavailable?

The graduate education system is a highly decentralized one, and attempts to direct it may have surprising and unintended consequences that could be harmful to the research enterprise as a whole; therefore, it is better to let the marketplace dictate policy, provide

students with the information and education they need to respond to that marketplace, and let academic institutions continue to decide, on their own, how many students are appropriate for their program and how long it should take students to attain a degree.

We have also not tried to make the PhD into a job-training degree. Making the PhD a more vocational degree would both dilute its value and require us to know the direction of future job growth, and history has shown how difficult this is.

How can reforms like this work in a system as decentralized as graduate education? I think there is only one way, and that is for the major participants — universities, government, industry, foundations — to get together around the table. While some major universities have been reluctant to consider reforms, I feel that these steps will strengthen an educational process that must change at least as fast as the society that supports it. Industry also must be an active participant, since there are indications that most job growth is taking place in the private sector.

I don't want to leave you with the impression that this is just another call for further study. Our committee is calling for consequential action and dialogue on our findings and recommendations. For this topic, however, where individual universities will have to hear from the rest of us and then make their own decisions, dialogue is the first crucial step to taking action. If all the participants in the graduate education system begin to talk to one another, then those with the power to implement the recommendations can begin to do so.

I'd like to summarize by telling you the top three actions items where your committee can specifically help support appropriate changes in the graduate education system. Note that none of these changes require additional funding--rather they just require reallocation of

funding currently available. These actions include encouraging NSF, NIH, and other agencies that fund graduate education to:

- **Adjust support mechanisms to include education/training grants to departments and programs.** These grants would provide financial incentives for universities to improve the versatility of graduate programs, provide better career information and guidance, and to control the time it takes to attain a degree.
- **Establish a national database designed and managed by the research community on employment options and trends.** This database could provide students and their advisors with more appropriate and timely information.
- **Improve the coverage, timeliness, and analysis of data on the education and employment of scientists and engineers.** This analysis should focus on the current employment marketplace for graduate scientists and engineers.

Thank you very much. I would be happy to answer any questions you might have about the report or possible actions that the federal government could take in this area.

******

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE

COMMITTEE ON
SCIENCE, ENGINEERING, AND
PUBLIC POLICY

REPORT BRIEF

Reshaping the Graduate Education of Scientists and Engineers

The graduate education of scientists and engineers -- an activity of growing importance in an increasingly technological world -- must change to reflect developments in science, engineering, the economy, and the broader society. With more than half of new PhDs going to work in nonacademic settings, graduate education needs to impart a broader range of skills. At the same time, the PhD should retain the features, including an original research experience, that have made it a world model.

The result of these changes, writes the Committee on Science, Engineering, and Public Policy in its report *Reshaping the Graduate Education of Scientists and Engineers*, would be a new kind of PhD, one that emphasizes adaptability and versatility as well as technical proficiency. COSEPUP, a joint committee of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, recommends that graduate programs provide a broader exposure to experiences desired by both academic and nonacademic employers. Faculty and institutions also should offer better career information and guidance to students so that they can make well-informed decisions in planning their academic and professional careers. Graduate education, ideally, prepares students for an increasingly interdisciplinary, collaborative, and global job market and should not be viewed only as a byproduct of immersion in an intensive research experience. The primary objective of graduate education should be the education of students.

The changing job market. Scientists and engineers with PhDs and other advanced degrees play a central and growing role in American industrial and commercial life. They contribute directly to the national goals of technological, economic, and cultural development -- not only as researchers and educators but in a wide variety of other professional roles. And as the country responds to expanded economic competition, urgent public health needs, environmental degradation, new national security challenges, and other pressing issues. A widening variety of professions and organizations are hiring the approximately 25,000 people who receive a PhD each year (up from about 18,000 a decade ago).

But a mismatch between the numbers of new PhDs and traditional research-oriented jobs in academia has led to considerable frustration and disappointment among young scientists and engineers. Fewer than one third of those who received PhDs in science and engineering in 1983-86 were in tenure track positions or had tenure in 1991. New PhDs are spending more time as postdoctoral fellows while they wait for permanent jobs to become available. Downsizing and restructuring in industry and government also have reduced the number of jobs focused on basic research in those sectors.

Despite the difficulties finding jobs in basic research, hiring in other areas has been vigorous enough to keep the overall unemployment level of PhDs relatively low. An increasing number of doctorate recipients are doing applied research, development, and management in industry, working in government or nonprofit institutions, or teaching in elementary schools and secondary.

A new PhD. COSEPUP found a common theme in its examination of the job market for PhDs. Many future job opportunities will favor students with a greater breadth of academic and career skills than graduate students typically acquire today. The committee therefore recommended a new model of PhD education that incorporates the following changes:

To foster the new model of PhD education recommended by COSEPUP, colleges and universities and their faculties should:

- Give students more options in pursuing the PhD.
- Provide a broader educational experience through such mechanisms as internships or minor degrees.
- Provide better career guidance and job placement to entering and graduating students.
- Control the time to degree.

- **More versatility.** Graduate programs, especially at the departmental level, should provide options that allow students to gain a wider variety of academic and career skills. Students who intend to seek a career in basic research should have a grounding in the broad fundamentals of their fields and should have some personal familiarity with several subfields. In addition, experiences that supply career skills beyond those gained in the classroom and laboratory, such as off-campus internships, could make graduates more effective in business, government, and academia at all levels. Many institutions have been experimenting with such innovations, providing a rich array of reproducible models.

Employers in all sectors value the requirement for original research that is the hallmark of the PhD. Hybrid degrees that do not involve such research have not been successful in the past. But a student interested in working in nontraditional fields should have the option to design a dissertation that meets high standards for originality but is more flexible in terms of time required, subject matter treated, and approach taken.

Students should:

- Obtain, before entering a graduate school, information on the employment pattern of the school's graduates.
- Pursue an education that provides a broad range of experiences.
- Press advisors for information on career options and realistic employment expectations.

- **Better career information and guidance.** The lack of accurate, timely, and accessible data on employment trends,

careers, and sources of student support is a serious flaw in the graduate education system. A national database that covers such issues as financial aid, time to degree, and placement rates -- including information gathered and disseminated through the Internet -- could help students and their advisers make informed decisions about professional careers.

• **Less time to degree.** The median number of years between receipt of a bachelors degree and a PhD in science and engineering has risen to more than eight years, an increase of about 2 years since 1960. The reasons for this increase are largely unknown, but some of it may be a result of students working as highly specialized research assistants or as teaching assistants in ways that do not directly contribute to their education. Each institution should set its own standards for time to degree and enforce them.

• **Education/training grants.** The heavy reliance on research assistantships for graduate student support has tended to make the needs of research projects rather than the students' educational needs paramount. Education/training grants awarded competitively to institutions and departments that emphasize adaptability and breadth could help develop and sustain locally developed programs.

Government should:

- Adjust support mechanisms to include education/training grants to departments and programs.
- Act to ensure continued diversity among institutions and research excellence.
- Help establish a national database designed and managed by the research community on employment options and trends.
- Improve the coverage, timeliness, and analysis of data on the education and employment of scientists and engineers.
- Facilitate a national discussion among representatives of government, academia, employers, and professional organizations to examine the goals, policies, conditions, and unresolved issues pertaining to graduate education.

COSEPUP saw no reason to recommend limits on enrollments or on the number of foreign students in graduate programs. Greater flexibility and more information in graduate programs will enhance the system's ability to mesh with the job market. And these changes combined with better precollege education will attract more American students to graduate education -- particularly women and minorities, who remain seriously underrepresented in some fields of science and engineering.

A shift in perspective In the past, graduates schools typically have seen their mission as producing the next generation of academic researchers. But scientists and engineers now contribute to national needs in many other ways. To contribute most effectively to the need for highly trained scientists and engineers, graduate schools need to review their missions and consider new approaches. If they do so, graduate education could play an even more important role in society than it has played in the past.

Committee on
Science, Engineering, and Public Policy
Study on Graduate Education

Phillip A. Griffiths *Chair*, Director, Institute for Advanced Study
Robert McCormick Adams, Secretary Emeritus, Smithsonian Institution
Bruce M. Alberts, President, National Academy of Sciences
Arden L. Bement, Basil S. Turner Distinguished Professor of Engineering, Purdue University
Elkan R. Blout, Harkness Professor, Department of Biological Chemistry and Molecular Pharmacology, Harvard Medical School
Felix E. Browder, Professor, Department of Mathematics, Rutgers University
David R. Challoner, Vice President for Health Affairs, University of Florida
Ellis B. Cowling, University Distinguished Professor At-Large, North Carolina State University
Bernard N. Fields, Adele Lehman Professor; Chairman, Department of Microbiology and Molecular Genetics, Harvard Medical School
Alexander H. Flax, Senior Fellow, National Academy of Engineering
Ralph E. Gomory, President, Alfred P. Sloan Foundation
Thomas D. Larson, Consultant
Mary Jane Osborn, Head, Department of Microbiology, University of Connecticut Health Center
Phillip A. Sharp, Head, Department of Biology, Center for Cancer Research, Massachusetts Institute of Technology
Kenneth I. Shine, President, Institute of Medicine
Ralph Snyderman, Chancellor for Health Affairs; Dean School of Medicine, Duke University Medical Center
H. Guyford Stever, Trustee and Science Consultant
Morris Tanenbaum, Vice President, National Academy of Engineering
Robert M. White, President, National Academy of Engineering

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1. How many institutions offer graduate degrees in science and engineering?

More than 600 public and private institutions offer master's or doctoral degrees in science and engineering fields.

2. How many graduate degrees in science and engineering are granted each year?

Approximately 80,000 master's and 25,000 doctoral degrees in science and engineering were awarded in 1993. This compares with 72,000 master's and 19,000 doctoral degrees awarded in 1986.

3. How many people employed in the US workforce have doctoral degrees in science and engineering?

The number of people who have doctoral degrees in science and eogineering from US universities and who work in this country was 437,000 in 1991.

4. What is the primary work activity of scientists and engineers with doctoral degrees?

In 1991, 36% were working in research and development (14% in basic research, 16.4% in applied research, 5.6% in development work), 15.6% were employed in management and administration, 22.7% in teaching, 9.1% in professional services, with the remaining 16.6% in a variety of other activities.

5. Where are scientists and engineers with PhDs employed?

In 1991, approximately 36% were employed in business/industry, 45% in 4-year colleges and universities, 6% in federal government (civilian), 2% in state/local governments, 3% in hospitals/clinics, 4% in other nonprofits, and the remainder in other activities. As of 1991, 31% of those who received PhDs in 1983-1986 had tenure or were in tenure-track positions in academic institutions.

Over time, the percentage going into academe has fallen steadily (from 57% in 1973 to 45% in 1991), and the percentage of those working in business/industry has increased (from 24% in 1973 to 36% in 1991).

6. What is the unemployment rate for scientists and engineers with PhDs?

The employment picture for scientists and engineers, especially for recent graduates, is not clear, partly because the pertinent national surveys of new and recent PhD recipients lag by several years. The picture is complicated by wide differences among fields, some of which are shrinking as others grow.

Overall, the 1993 unemployment rate of 1.6% for all scientists and engineers with PhDs and 2% for recent recipients of science and engineering PhDs compares favorably with the overall unemployment rate of approximately 6% or more, the rate of 2.6% amoog general professional occupations, and the rate of 3% among those with at least a college degree.

Although relatively low, the level of unemployment among science and engineering PhDs has increased over time (from 0.8% in 1985 to 1.6% in 1993 for all; from 1.5% in 1985 to 2% in 1993 for those 1-2 years after receiving their PhDs).

At the same time, however, recent surveys by new graduates looking for jobs in the first few months after earning their PhDs have reached double digits in some fields, much higher than in the 1980s, indicating that it is taking longer to find an initial position.

7. Is science and engineering graduate school enrollment increasing or decreasing?

Growth in the total science and engineering graduate-student population has averaged about 2.5% per year since 1982. Most of the net growth in recent years was due to an increased number of foreign students with temporary student visas. This group received 32% of the doctorates in 1992 (up from 19% in 1982). Historically, about half of these students leave the US after receiving their degree or after serving a postdoctoral appointment.

The total number of women in graduate schools rose by about 3% per year compared with about 1% for men. In 1992, women received 28.5% of the science and engineering doctorates, compared with 23.7% in 1982. The percentage of science and engineering doctorates awarded to underrepresented minorities rose from 4.1% in 1982 to 5.5% in 1992.

8. How long does it take to attain a graduate science and engineering degree?

The median number of years between receipt of the bachelor's degree and a doctorate in science and engineering has increased from 7.0 years during the 1960s to 8.7 years for those who received doctorates in 1991. Graduate students in the physical sciences have shorter-than-average overall completion times—about 7 years—and social scientists have longer than average completion times—about 11 years. The median time registered in doctorate programs of 6.7 years is shorter than total time to degree because many graduate students take some time between college and graduate school to work, and some take time off during graduate school.

9. How are full-time graduate science and engineering students supported financially?

In 1992, 41% received their primary support from their institutions, 31% provided most of their own funds, and 20% depended primarily on federal sources, in the form of research assistantships, graduate fellowships, and training-grant positions. Federal support for students in the biological and physical sciences was higher (34% and 36%, respectively). One-fourth of those with institutional support received it in the form of research assistantships, half received teaching assistantships, and the remaining one-fourth were supported by a mix of fellowships, traineeships, and other forms of support. However, the preceding discussion probably underestimates the amount of federal support, because the source of a graduate student's support typically changes from year to year.

10. How many postdoctoral appointees are there?

There were approximately 24,000 science and engineering postdoctoral appointees in doctorate-granting institutions in the fall of 1992. About 53% of them were foreign students.

Reshaping the Graduate Education of Scientists and Engineers. Washington, DC: National Academy Press, 1995.

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Mr. SCHIFF. Thank you, Dr. Griffiths.

Because we have a number of members here, I am going to proceed with questions under the five-minute rule, which will apply to me also. But if any member has a burning line of questions that they didn't get completed during the five minutes, if they ask for some further recognition, I will be glad to extend it.

We have just been joined by Congressman George Brown of the State of California, who is the ranking member on the full Committee.

Congressman, I would like to ask if there is anything you would like to say in the way of an opening statement before we proceed with questions.

Mr. BROWN. Thank you very much, Mr. Chairman.

I assume that I have a prepared statement. I ask unanimous consent to put it in the record.

Let me just say that this is a very important subject, which is attracting interest on campuses all around the country. I observed that during my visits. It is kind of an underlying problem that doesn't rise to critical attention easily. But the developing of understanding and possible solutions to it is one of the important areas this Committee can provide a service in, and I would appreciate your proceeding with the hearing on it.

Thank you.

Mr. SCHIFF. Thank you, Mr. Brown.

I want to say that all opening statements will be admitted as part of the record.

Dr. Griffiths, I would like to ask you about two things, if I may. The first is, this is ancillary, I know, to what you were looking at, but I wonder if you ran into it; that is, there is an issue that has been constantly appearing in the national news that goes something like this. Universities have become overly interested in research, perhaps for a variety of reasons, including perhaps the income that is derived from that, to the extent that it has created an imbalance in the classroom, particularly down at the undergraduate level of education.

I am sure you have heard this line of reasoning, and I have heard it in the national news a number of times. I wonder if you could address it in terms of whether you agree that it is a concern or you feel that it is exaggerated or where you would place it.

Dr. GRIFFITHS. I think the issue between research and education is not an either/or issue but it is one of balance and one of integration, the transmission of knowledge through the educational process and the generation of new knowledge through the research process.

I think that many institutions do an excellent job at the undergraduate level in having programs that are balanced as far as the emphasis given to research and to undergraduate education. Other institutions, I think, could improve their programs.

There are a number of ways that this can be done. I know this is very much on the minds of university faculty and university administration. I observe that my own graduate students now are much more concerned about their ability to communicate their subject effectively, including teaching it, as that is now something that

is part of the job interviewing process in a way that it was not some years ago.

So, I think that the issue you have raised is an important one. It is one that is on many people's minds and is one that I think at the moment is being worked on rather constructively in a number of places.

Mr. SCHIFF. Thank you.

The second issue I would like to raise is the Subcommittee is probably overly accustomed to my referring to my older brother, who has a Ph.D. in physics, but that is where I got most of my learning about science and engineering. One item I recollect from family connections is my brother in high school in, I believe, 1957 when the Russians orbited Sputnik. There was this great hue and cry that we need more American scientists and engineers. My brother decided this is what he would do.

When he got his bachelor in science degree in 1963, the job offers wouldn't stop coming in. But by the time he got his Ph.D., which was some number of years later, the situation had changed dramatically and employment during that era was extremely difficult to come by for Ph.D.s.

What this says to me is we have trouble with the long-range plan. In other words, we don't produce Ph.D.s next day. It is a number of years before a high school student decides to go into any kind of science profession, gets to the point of a Ph.D..

What do you recommend? We have done previous reports, I know, on this subject. But what do you recommend? How can the United States plan efficiently in one year, down the road, so that the people it is trying to encourage to go into certain lines of study will have employment at the other end of that line of study?

Dr. GRIFFITHS. Mr. Chairman, this is, I think, a very important and complex question. When the committee, COSEPUP, discussed this, which we did at some length, we felt that the current system as it stands is not sufficiently flexible or adaptable to adjust to changes as they are occurring. To oversimplify, we imagine the Ph.D. experience might go as follows:

First, students would decide whether or not to enter graduate school based on much more complete information than they have at the moment.

Secondly, graduate school would be a series of decision points. The first decision point would come after two years, when you complete your qualifying exam. At that point you decide whether to continue to get a Ph.D. or whether, for example, to take a masters degree, perhaps combine it with a masters in some other field, and go out into the workplace.

If you decide to continue with the Ph.D., you might do so with the idea of entering a research career or going into work in the private sector, in the service sector in some nontraditional way.

Then you would design your curriculum and your courses differently. If you wanted to go to work in nontraditional areas, then you would probably take courses outside your department. You would take interdisciplinary courses, perhaps, but you would have the flexibility so that you could design your graduate education program in response to the employment picture as it was evolving.

The whole process ideally should take five years from start to finish, with the decision point, in two years, as I said, three more years till your degree. And I think with better information in the system, shortened time to degree, and some model of this kind where there were branching decision points, the system would be more adaptable.

Mr. SCHIFF. So your response is. We need more checkpoints instead of a continuum that just goes on for years with no flexibility; there should be points of reevaluation of the student, combined with more current information about the market and then more choices for the student to make?

Dr. GRIFFITHS. That's right.

Mr. SCHIFF. Thank you.

Dr. GRIFFITHS. And there are institutions, by the way. This is not an original idea. I think one of the things that struck us when we did the study was the large number of panels we brought in. There is a tremendous amount of creativity already going on in various universities, and there are graduate programs that are modeled on this concept. So everything we recommended is actually being done somewhere.

Mr. SCHIFF. It is a lot different from what I remember seeing, which was this kind of a tunnel. You start at the beginning in late high school and are expected to come out some number of years later at the other end. But there were no exits from the tunnel. You were just in it once you were committed. So I appreciate that approach.

Mr. Geren?

Mr. GEREN. Thank you, Mr. Chairman.

Just a brief follow-up on the points you made. I wonder if the problem isn't so much the information that students have as the responsiveness of the institutions to the students' needs. I think of my tenure in graduate school, which was law school, that the grapevine's pretty good about the job market. Students, you know what's going on out there. You've got folks going out in it every year.

It seemed to me that the students would be a great resource to identify the problems if we could just get the institution to respond to what the students' needs are, and not have the academics kind of locked in this tunnel that the Chairman described.

I can remember my first year in law school, second year in law school, third year in law school as we watched our third-year folks going through the employment process. The word gets around pretty quickly about where the opportunities are and where they're going. But the curriculum doesn't change, the institution doesn't change.

I was in school during some tumultuous times in the Texas economy, and the school was probably the last to know it. It seems like the students were a pretty good resource. I remember my undergraduate years, I went to an engineering school, and there were big changes in aerospace engineering, and the students were bailing out of those fields very quickly. They just saw the writing on the wall. The institution wasn't really changing.

So it seems to me in some way there should be some way to make sure that the institutions are more responsive to this infor-

mation coming through the grapevine. There is nothing focuses your attention more than knowing that in a couple of more months the old scholarship is going to run out or the check from home is going to stop and you've got that family to feed. You do a pretty good job of finding out what is going on out there; making sure that somehow we get the institutions, and perhaps to the extent we can influence those institutions, to respond and not be locked in their old mentality.

Did your committee discuss the right proportion of the mix of graduate research assistantships, traineeships, and fellowships for the support of graduate students in science and engineering? And I would just ask whether or not you think the majority of support should be through assistantships and fellowships, since these mechanisms seem likely to place the most emphasis on the educational goals of the people?

Dr. GRIFFITHS. We discussed this at some length. I think we did not come up with a recommended number about the distribution of funds between research assistantships and other means of support, fellowships, training grants, education grants.

We did feel that some experimentation, and in fact, some experimentation is already under way, with a further experimentation shifting some of the funding from the research assistant mode to other modes that were more directly linked to the education of the student and, in particular, would provide some greater opportunity for options for graduate experience and that was desirable.

So the general recommendation was the shifting of funds from the RA to other means of support. But what the mix should be, I think we don't know. I think we felt that some experimentation was called for.

Mr. GEREN. When you say experimentation, what do you mean by that? Actually formally experimenting with different mixes at different universities, or how would you propose to go about reaching that recommendation?

Dr. GRIFFITHS. Well, for example, within the National Science Foundation, in the engineering directorate they already are doing experiments with different kinds of support for graduate students in engineering, which are much more directly focused and providing the students with an education that gives them greater flexibility when they graduate.

So that would be the type of program we had in mind that could be used in the other sciences.

Mr. GEREN. Thank you. I think my five minutes is probably up. Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Mr. Geren.

Mrs. Morella?

Mrs. MORELLA. Thanks, Dr. Griffiths. I appreciate your presenting a report to us. I recently spoke at a space industry roundtable and during the Q&A a young man stood up and he said, "Mrs. Morella, would you tell me where I can get a job as an engineer?" He was a young man. He found that there was just no room in the inn for him. It was a tremendous question, particularly in light of the downsizing that is going on in government that has an effect on the private sector.

I just wonder, and also with many people who have been in these positions for years, who are not relinquishing them even though in the Federal Government we have buyouts, et cetera.

Would you like to address that beyond the report and questioning that we have already had? I know you talk about—well, I guess I could point out another thing. I am not sure that graduate institutions are doing more than caring about just getting the tuition dollars and having the classes set up for Ph.D. candidates, but I am not sure that they even know what is going on in the real world in terms of job placement and career opportunities.

Did you confront any of those two points. The young person really has a dilemma, and that we need to get higher educational institutions on the ball?

Dr. GRIFFITHS. Yes. We did. I think one of the things that was most striking to the committee as we had panels come in was the increasing variety of careers that people with Ph.D. training can go into, careers in which perhaps not directly are not research jobs but they will use very much the educational experience that they have, the resourcefulness that they develop when they design and carry out original research experiments, things of that kind.

To give you an example in my own field of mathematics, one of the premier institutions for graduate training of mathematicians, Columbia University, has recently put in place a dual-degree program. You either go through and get the traditional Ph.D., expecting to teach in universities, or you get a Ph.D. which has emphasis in mathematics and finance.

Increasingly, finance is no longer accounting, it is applied mathematics. You see mathematicians working on Wall Street, in the treasury office of major corporations. All financial decisions ultimately are in some way based on a complex mathematical model.

Mrs. MORELLA. But you are going to have to get these institutions to make sure that they see this report and act on it.

Dr. GRIFFITHS. I agree. But I see change occurring. I think it needs to be accelerated and much more needs to be done. But change is beginning to occur in the system also.

Mrs. MORELLA. Since my five minutes aren't up yet, Dr. Griffiths, I notice one little two-sentence paragraph under your recommendations, general recommendations, which says attracting women and minority group members. You simply say, "Where it appears that the number of women and minority group members is low in particular fields, deliberate steps should be taken to deal with real and perceived barriers to full participation."

I feel that it is important enough that more attention maybe was paid to it or certainly should be paid to that when we know that two-thirds of the entrants who are going to be entering the workforce are going to be women and minorities. Would you like to comment on that?

Dr. GRIFFITHS. One of the panels who were to meet with the committee consisted of people who are generally represented, at least in a number of areas in science and engineering. I think that statement was formulated pretty much as the result of the way the issue was framed by that panel.

They saw that there were barriers. Many times they were not barriers that were in any way explicit but they were implicit in the

system. There was insufficient encouragement, there was insufficient flexibility. And the statement, as we put in there, that these barriers should be recognized and dealt with I think reflected the sense of that panel who came to meet with the committee.

Mrs. MORELLA. I just feel it doesn't go far enough. It's almost patronizing, in a way. You see what I am saying? It is a very important point.

Dr. GRIFFITHS. I agree.

Mrs. MORELLA. It is too bad that more wasn't done to explore what some of these barriers may be, real and perceived. Maybe there will be follow-up.

Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Mrs. Morella.

Mr. Luther?

Mr. LUTHER. No questions.

Mr. SCHIFF. Mr. Luther has no questions.

Mr. Bartlett?

Mr. BARTLETT. Thank you very much.

I wanted to address for just a moment the concern you have about how long it takes to get a degree. When I finished my doctorate, that was a long time ago, in '52. It took five years. That was a very long time then, and it was a long time because for the last four years I had the privilege of being invited to join the full-time faculty at the university. It would only permit me to take five or six hours a semester, and it takes a while to get enough courses to get your Ph.D.. It is now a much longer time, I take it.

I have had the privilege through my life to work in about every place you can do research. I worked in a university where I had grants and contracts and used graduate students. I worked for government doing research and R&D later. And I worked in private industry where I was doing R&D.

Of all of those places, certainly you get more productivity for your dollar in the university setting because you have slave labor available, the graduate students.

I was wondering if one of the reasons for the extension of the time that it takes to get the Ph.D. is the desire to maintain this slave labor force for a longer period of time. What are the things that are driving lengthening the degree time for science, math, and engineering?

Dr. GRIFFITHS. We discussed this at some length and were unable to in any way come up with data or documentation to get a clean answer to that question.

I think one suggestion that was made is that there is just much more complexity in science these days and you have to just take more time to learn.

Another was that the students themselves extend the time because of the difficulties in getting employment when they get through.

Still another was that having a graduate student to work on your research project is a way of getting that research done, and there is not that much incentive for the faculty member to move them through.

Having been a provost at a major university, Duke University, I also observed that in a professional schools, the medical school,

business and law school, where there was a fixed time limit, there was more effort put forth by the faculty member in designing a curriculum that would cover the central knowledge within that given time frame. So there was a discipline that I think was in the professional schools that I did not see in the arts and sciences, more in the arts than in the sciences.

But I think there could be further effort on the part of the faculty to impose some discipline on the system and get the time to degree down.

The factor you mentioned is perhaps one, but I would not even say it is the major part of the story.

Mr. BARTLETT. But there is an interest in looking at why this has been stretching out and seeing if it can't be shortened.

Dr. GRIFFITHS. Yes.

Mr. BARTLETT. Just one last question. The second of your recommendations was to establish a national database designed and managed by the research community on employment options and trends. I think the proper role of bureaucracy and government is to educate, not to control. I was very pleased in the report that you indicated that you saw no reason that there should be any efforts made to control the number of persons who went into graduate school or those who exited with a degree.

How would this be done? Would it be the professional societies or the universities? Who would have the responsibility for establishing this national database?

Dr. GRIFFITHS. I think it could be done in a number of ways. One way would be that the National Science Foundation, through Science and Engineering Indicators, which is the official data concerning the science and engineering enterprise, could take the lead.

But I think they should work with the professional societies because there is great variation by discipline and by profession, and the professional societies are far along, in many cases, with having data that is quite interesting and intricate and reflects, I think, much more current information than is generally available in the NSF Indicators or has been available.

So I think with the NSF Indicators taking the lead role but working with the professional societies, it would be one way that this might be accomplished.

Mr. BARTLETT. I have personal family experience in how important this is to students. Our last of ten children is just completing his degree in chemical engineering. He was going to be an engineer, and he knew that, but which one of the subspecialities he was not certain of. His decision was based largely on the marketplace and which graduates were getting hired most quickly and being paid the most.

So I think that this kind of information is going to be increasingly valuable to our young people as they look ahead and responsibly try to plan their lives.

Thank you very much for your testimony.

Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Mr. Bartlett.

Mr. Brown?

Mr. BROWN. First let me thank you for what I think is an excellent study, in line with the tradition of excellent studies that the committee has made over the years.

One question I have, only. The problem that is being discussed here is not unique to the United States, it is also occurring in other countries. The British have tried to deal with it, and others.

To what extent did you consider their experience to try and draw relevant conclusions that would include the kinds of solutions that they have come up with in some of these other countries?

Dr. GRIFFITHS. We thought about these to some extent. For example, in the U.K., there was recently a reform of their graduate education system. There is a white paper on that. I think in the case of the U.K., it is a much more highly centralized system than we have here. And the kinds of policies that they have implemented, some of which they just now, I think, are changing back to previous ways, the kinds of policies that they implemented would not be as appropriate for our system, as highly decentralized as it is.

The same is true also of the French and the Germans.

The main difference that we saw was that in this country we do have a highly diverse and decentralized operation, and so the sorts of actions that were being taken, for example, in the U.K. we felt would not be appropriate for here.

Mr. BROWN. Yet in the U.K., as I recall, some of the same kinds of recommendations were made; for example, putting greater emphasis on the possibility of stopping the graduate program at the masters degree level and going into industry.

And in the German situation, a good deal of their research capability is located in the institutes, the Max Planck Institutes, for example, and there have been some recent exchanges between the leaders of that sort of activity in Germany with the United States, looking at the possibility that perhaps we could move in that direction as a way of providing additional research opportunities outside the university setting.

I think these are relevant explorations that we need to look at as part of the overall solution to our problem.

Dr. GRIFFITHS. I agree. I think that, for example, the U.K. placing greater emphasis on the masters degree, we were aware of that and commented on that in the report.

What we did not do was to suggest that this be something that was required in any way. That is, I think, the difference.

Mr. BROWN. Thank you very much.

Mr. SCHIFF. Thank you, Mr. Brown.

Mr. Boehlert?

Mr. BOEHLERT. Thank you very much, Mr. Chairman.

Dr. Griffiths, that is an excellent report. What it says to me—I was educated as a public relations man, that is as far away from science as I can think of—is that we are doing pretty well here, but we need some tinkering at the margins.

But when I read a report that talks about the myths, unemployment at 1.6 percent, hell, that's not unemployment, that's full employment. When I read further that some of the graduates are feeling the pain of unmet expectations, I say what's new. You're joining the rest of us in this world.

[Laughter.]

Mr. BOEHLERT. My point is I think we are doing a lot of things exceptionally well. I like all of your suggestions. I am particularly enamored with that portion of your report and testimony which would point out that employers place high value on scientists and engineers who can communicate, collaborate, and work across disciplines. I think it is critically important. If there is any failing in our educational system for scientists and engineers that I perceive, it is that sometimes that education is too narrow and the ability to communicate somehow is lost in the shuffle.

But overall, the only thing that I am appalled by and I agree a thousand percent with your recommendation, and that is that we have got to tighten up the length of time to get these graduate degrees. It is ridiculous. If we keep going in the way we are going, pretty soon you will find newly minted Ph.D.s 50 and up, and they will go take their degree over to the social security office.

[Laughter.]

Mr. BOEHLERT. My colleague, Mr. Bartlett, pointed out something that we have observed that needs to be addressed. I just want to thank you for an excellent report. I don't have any great questions or any words.

Mr. SCHIFF. Will the gentleman yield?

Mr. BOEHLERT. I will be happy to yield.

Mr. SCHIFF. I appreciate that.

I agree with you that the unemployment figure seems very low for people with Ph.D.s. But I think in this area I wonder if the underemployment factor isn't very large. I assume that with a Ph.D. an individual can find employment. But I wonder how close or far away it may be from what we would expect somebody with a Ph.D. to be doing as a career.

I wonder, with your permission, I would turn to Dr. Griffiths with that observation to see if you agree or disagree with it.

Dr. GRIFFITHS. What we found was, even though there was low unemployment, that the difficulty in passing the transition from the Ph.D. to a full-time job was already, I think, a major problem and was getting worse. So that the data are data. That's what the situation is. But it does not reflect the difficulty that the system has had in adjusting to the marketplace at the moment.

So, underemployment I think is a concept that we talked about but had difficulty with because it is hard to define precisely and when somebody is underemployed in one person's view it may not be in another person's view.

Mr. BOEHLERT. I would suggest that the definition is a real troubling aspect of this. If you have a Ph.D. flipping burgers, that is obviously underemployment. But if you have a Ph.D. working some place making $57,000 or something, and he is not particularly excited about what he or she is doing, does that constitute underemployment? You know, I would say maybe it is better to meet expectations.

Dr. GRIFFITHS. I think what was found could be illustrated by one person who testified in front of the committee who was a physicist, and that individual now has a job that he loves. He is a physicist, he has been hired by a pharmaceutical designing instrumenta-

tion for their R&D enterprise, but it took him six or seven years to end up there.

So, on the one hand he loves what he is doing and makes use of his Ph.D. training, but he was extremely angry at the experience he had in trying, through postdocs, not finding academic jobs, finally ending up working with this pharmaceutical.

Mr. BOEHLERT. I just wonder, when we are talking about definitions, we have a Ph.D. and a physiologist, and Dr. Ehlers, who is not here right now who is a Ph.D. in physics, are they underemployed because they are Members of Congress?

[Laughter.]

Mr. BROWN. Would the gentleman yield to me?

[Laughter.]

Mr. BROWN. On that same line, you have commented on the phenomenon of the itinerate postdocs and the longer period of time that people are remaining at this postdoc. Is that considered employment, or is that slave labor?

More specifically, what is the salary range for these large number of postdocs who float around for years at a level which I understand is below the ability to sustain themselves? Did you collect figures?

Dr. GRIFFITHS. No, sir, we did not collect data on the salary levels of postdocs, the length of time people are in postdocs. I think that is an important issue, and it is one that was increasingly raised during the discussions we had. But we focused primarily on the Ph.D. educational experience. I think the postdoc is something that does need looking at, but that was for another study.

Mr. BROWN. Originally, the postdoc was supposed to be a part of the educational experience. Now it is a never-neverland. It is neither employment nor educational in some cases. We need to analyze that problem because if that becomes the fate of a large percentage of the people who get the Ph.D., it distorts the picture considerably.

Mr. SCHIFF. The gentleman from New York's time has now expired.

Mr. Doggett?

Mr. DOGGETT. Thank you, Mr. Chairman.

Dr. Griffiths, I enjoyed looking at your report. I think it is an excellent analysis. I know that quite appropriately many of the recommendations are directed to our universities. But I would like to focus just for a moment on the fourth recommendation, concerning a possibility of a new class of education and training grants that would allow students to choose training that will better fit them with the matching level of the job market.

My question is can you give us any more specifics on your thoughts, since that is something that certainly fits within the jurisdiction and scope of this Subcommittee, as to how that might work, how these education and training grant programs might work, which agencies, how they would be structured, and whether there are any models out there that we can focus on?

Dr. GRIFFITHS. Yes, sir. We felt that it was more appropriate for the committee to focus on what the objectives of these education/training grants might be rather than to suggest the specific design that they might follow.

I think the appropriate agencies are certainly the NSF, and it is already doing some experimentation, as I mentioned earlier; the NIH, which has a superb and longstanding track record in training grants to encourage interdisciplinary work, would also be an appropriate agency.

We felt it was more our role to, as I said, put forth suggested objectives of these grants to increase greater versatility and flexibility of graduates, shorten the time to degree, developing communications skills, things of that kind, and leave it up to the agencies to design specific programs that would implement those objectives, achieve those objectives as best they could.

Mr. DOGGETT. Thank you.

Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Mr. Doggett.

Mr. Gutknecht?

Mr. GUTKNECHT. Thank you, Mr. Chairman.

Several questions that I was going to ask have already been asked, including one that Mr. Brown raised about the salary levels of some of these people. But I would like to change the direction a bit.

One of my concerns, and this is more of an observation you can respond to it if you like, is that our entire education system literally from kindergarten through postgraduate school in the United States is about training people to find jobs working for somebody else.

I try to do at least two or three plant tours in my district every month. What I find is that there are an awful lot of these new businesses and really exciting new companies that are starting out there that have been started by people who, in many cases, were engineers or had advanced degrees, working for somebody else and they decided to go out on their own.

But the observation is that our educational system really does not teach entrepreneurial skills. Have you come across that? Do you have any observations in that regard?

Dr. GRIFFITHS. I think the point of contact of our study with what you have just said was the point made to us by many of the employers, including some who were in start-up companies, small and mid-size companies, consulting firms, who pointed out that the Ph.D. experience where you have to design and carry out a research project was one way of developing in the individual the resourcefulness and creativity that goes with entrepreneurial skills. So that the part of the Ph.D. educational experience, centering around the thesis, was in fact a vehicle that could help to develop exactly those skills on the part of the students who go through the process.

Mr. GUTKNECHT. Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Mr. Gutknecht.

Mr. Doyle?

Mr. DOYLE. Thank you, Mr. Chairman.

I don't have any questions at this time.

Mr. SCHIFF. Thank you, Mr. Doyle.

Mr. Graham?

Mr. GRAHAM. I have no questions.

Mr. SCHIFF. Mr. Graham has no questions.

Ms. Lofgren?

Ms. LOFGREN. I guess I have been thinking about this. There is a role for the Federal Government in the grant programs in universities.

One of the issues in terms of the employment of people is not just are they employed but how are they employed, doing what? If you are a postdoc and you are earning $30,000 a year with no job security and working long hours, you have got to question, I think, whether you made the right career decision when you could have been going to law school and earn double.

So, I guess the question is what role could we play to impact society, because I think it is a societal issue, where young people coming up that could go into a variety of fields and earn more money than the brightest children in the country going into physics or advanced sciences are just not remunerated in the same capacity when they are employed?

It is sort of a broad question. What can we do to impact that whole societal issue?

Dr. GRIFFITHS. I think one of the concerns that certainly I have as a scientist and I think my colleagues in the scientific community have is just this point, attracting the talent into science and engineering that we as a country need.

I think one aspect of this that should not be forgotten is just the pleasure that one gets in doing research in science. You know, that is a benefit that we as a profession have that I think is probably unique to science and engineering.

So I think in thinking about the employment, which is a primary concern to us, we should not lose the fact of just the beauty and the joy in being a scientist or an engineer. That is something that we need to communicate to our students better and for them to see as one aspect of a career in research that is probably hard to match if you are a lawyer or a businessman.

Ms. LOFGREN. Every lawyer and businessman might not agree with you. Most of us who are in professions, with the exception of the Members of the 104th Congress, do enjoy what we are attempting to do.

[Laughter.]

Ms. LOFGREN. I guess the question is what do we do, how do we assist if there is a positive role for us to play? It is fine to have delight in discovery, and I am sure you are correct the scientists and engineers who I have personally known; but, if you are unemployed, or at the end of your Ph.D. and postdoctoral work you are pulling in $25,000 a year and you can't pay off the loans, you can't get married, you can't have a family, you can't buy a house, and it does really cut into the delight you might have in experimenting and creating and learning.

It seems to me that that is a major issue, not just for this Committee but for this country.

Like I say, I talked just a month ago to a Russian emigre to the United States whom I know personally who was just stunned that he has a number of advanced degrees in computing science and Russia's economy is in complete disarray but still those who are in science are the intellectual elite of that country and, to the extent there was compensation, they were esteemed. And he was observ-

ing that any smart student in this country goes to law school instead.

I guess that is the nub of the question. How do we provide at least a minimum level of employment and income so that bright minds can do what our country needs them to do, which is to go into the advanced sciences?

I think the report is useful, but I am not seeing a path to resolve that question. Maybe it is not resolvable with one answer, but I think it is a major challenge that we have to face.

Dr. GRIFFITHS. There was an earlier report that COSEPUP prepared which was released two years ago where we proposed certain national goals for the level of support in science and engineering.

I think if there were a sense of how much science is enough and that this is the level of support that will be there, and there was some predictability and if there were information systems so that students knew what to expect realistically, that having this available would help the situation.

I think many students went into graduate school expecting one thing, they found quite a different thing when they got through. They ended up doing something that they had not expected to do. They actually love what they are doing, many of them, but they are still bitter about how they got from A to B. So we need much better, I think, information in this system, and I think we need to sort out what we as a country feel is the appropriate level of support of the science and engineering enterprise and have that known.

Mr. SCHIFF. I have to say the lady's time has expired. If the lady desires an extra two minutes, we will extend it.

Ms. LOFGREN. No, thank you, Mr. Chairman.

Mr. SCHIFF. Thank you very much.

Mr. Weldon?

Mr. WELDON. I thank the Chairman.

I apologize for not being here for your earlier testimony, sir. I was in another committee markup.

I consider this a fairly important issue. When I was an undergraduate student, I contemplated graduate school as opposed to medical school, which I did pursue. One of the things that did encourage me to pursue medical school was seeing one of the graduate student teaching assistants in the course I was taking. He was approaching graduation and having problems finding the type of employment he wanted, which was an academic post.

I guess my question to you, which I am not sure you covered in your testimony, is the tremendous proliferation of universities in our Nation in the past 40 years, how much of that is playing a role in the situation that we are seeing here.

I represent Florida, but I grew up in New York, and I know when I was a child growing up in New York, the governor at the time, Nelson Rockefeller, took a bunch of teachers colleges and turned them into universities. And there are a lot of universities today in America training graduate students that didn't exist 30, 40 years ago.

We are playing somewhat of a role in that in the proliferation of these institutions through the granting process that is made available, and I wonder if you would just comment on that. You may

have said something earlier in your statement about it, and I apologize if I am asking you to be redundant.

Dr. GRIFFITHS. The committee did not discuss at any length whether there was overcapacity or overexpansion of the university system.

We discussed briefly whether there should be any sort of accreditation process, which there is not currently, for Ph.D. degrees. I think the experience that I have had with accrediting did not give me a lot of optimism that this would help and improve the current situation.

I think what we felt ultimately was that if we could get much better information into the system so the students could make more informed choices so that faculty can be much better advisors to their students, then the market conditions would be the best way to determine the size of the system.

You know, if you have too many universities and if students make informed choices not to go to graduate school, then you will see small or disappearing graduate programs. In fact, that is already happening.

So, rather than make a statement that the number of programs that can award a Ph.D. in chemistry should be limited to 150 or something of that sort, we felt it was much better to simply have a system which is well informed and let it raise its own interim adjustment.

Mr. WELDON. Thank you.

Mr. SCHIFF. Thank you very much, Mr. Weldon.

Just as I said, it was a privilege to have our two researchers on this Subcommittee, it is a privilege to have one of our physicians in Congress on the Subcommittee also.

Ms. Jackson Lee?

Ms. JACKSON LEE. Mr. Chairman, thank you very much.

I really want to applaud you and the ranking member of the Subcommittee as well for this hearing and the information that we are able to glean from this.

Let me acknowledge and apologize to Dr. Griffiths. I was detained as well and may not have had the full opportunity to hear all of your testimony. But I am interested in the concept, and maybe you can explore it a little bit with me, since I haven't been in college maybe just yesterday or a few years ago.

I had the opportunity to interact with graduate students, and I think the importance of your focus about training and hands-on versus just being maybe led around is a very important aspect of the training direction.

Help me with that in terms of what we might do at this level to ensure, whether it deals with the funding, whether it deals with ultimately the kind of partnerships the Federal Government has in helping graduate training be more hands-on and thereby create an excitement of our future scientists to be more creative and productive.

Dr. GRIFFITHS. The committee found that the graduate education system, at least for the last 20, 25 years, has been largely driven by the research system. There has been no, if you like, human resource policy for the education of advanced scientists and engineers.

Most of the financial support or Federal financial support of graduate students is through engineering assistantships; I think about 85 percent. We felt that it was time to really think about what the educational policy should be for the training of advanced scientists and engineers and to recast the Federal support for graduate students with the educational objectives in mind, and those objectives, as discussed in the report, should be more hands-on experience, provide the options for greater flexibility, choices, things of that kind.

So I think the role the Federal Government can play, one role, is to encourage the efforts. Are any underway? To some extent, NSF and NIH—to think of the financial support of graduate students as enhancing their educational experience and providing them a greater set of options than has been the case.

Ms. JACKSON LEE. Let me just throw out for you the possibility—and this may be ongoing, you need to help me with this as well—whether a greater participation in the labs, greater participation, again, possibly, in an internship fellowship component at NASA or the space station, potentially, as we work toward funding those particular entities.

What about opportunities along those, that is Federal obviously, opportunities? I am sure there is private sector. But how would that fit into the scheme of the direction that your report has taken?

Dr. GRIFFITHS. I think it would be very consistent with it. Any sort of greater set of options for students as they come through graduate school to broaden their experience hands on, see what it's like working in industry or working in a Federal lab, I know that within the NSF, within the engineering directorate now, they have a very fine experimental program where graduate students, partly funded by NSF, partly funded by industry, split some of their time doing their thesis project.

So all of these kinds of experimentation and experiments that work and develop them into programs I think could improve the system.

Ms. JACKSON LEE. My last question that I would like you to focus on may be beyond the boundaries of what would be exciting for a graduate student. But I continue to ask a series of questions about how we can continue to excite those primary and secondary students. So I would offer, say that I would encourage graduate students to spend a day at their local school and be engaged, if you will, whether it be volunteer, whether it be a component of their training, to provide that base for us in the 21st century.

The other question I would ask you to respond to is the continuing concern about women and minorities in the sciences and certainly at the graduate level and what we do there, starting at an early age or however we expose that population to this important work.

Dr. GRIFFITHS. One of the recommendations of the committee was shortening the time to the degree. But we did not say that this should be mandated or that it should be five years or six years, because, for example, many women as they go through graduate school will have a family and I think students that come from different backgrounds that may not have the resources to be able to

go through graduate school without taking time off to work, we need to have the flexibility in the system for that.

So, even though as a general policy we felt that the time to degree could be shortened, we did not feel that this should be legislated. In particular, we want to make sure that the system is as open as it can be to groups that have not traditionally participated in it, and a conscious effort should be made to have policies that encourage this.

Ms. JACKSON LEE. A certain amount of outreach?

Dr. GRIFFITHS. That's right.

Ms. JACKSON LEE. Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Ms. Jackson Lee.

Although I would like to move on to our next panel, I would like to ask one time if any member really has a question they didn't think of and didn't have a chance to ask before.

Mrs. Morella?

Mrs. MORELLA. Mr. Chairman, I have a question, just a point of observation, in terms of striving to strike a balance. I counted the number of people on the panel, and there were 19. Of the 19, there was one woman. I know you had nothing to do with putting it together, but in light of my concerns and the concerns expressed by Ms. Jackson Lee, I think that as we put these panels together, there should be somewhat more balance.

Thank you.

Thank you, Mr. Chairman.

Mr. SCHIFF. Dr. Griffiths, I want to thank you, first of all, commend you on an excellent report from you and your committee, and I want to thank you once again. I know this isn't your first visit before a congressional committee, but thank you for the contribution you have made with your testimony. Thank you very much, sir.

Dr. GRIFFITHS. Thank you, Mr. Chairman.

Mr. SCHIFF. I would like now to welcome Dr. Neal Lane, who is director of the National Science Foundation, and Dr. Harold Varmus, who is the director of the National Institutes of Health.

Gentlemen, as you both know, your written statements have been received and, without objection, will be made a permanent part of the record of this hearing.

I invite you to proceed and summarize as you both see fit.

Dr. Lane, our Subcommittee has jurisdiction over your agency.

[Laughter.]

Mr. SCHIFF. So we will recognize you first.

STATEMENT OF DR. NEAL LANE, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. LANE. Thank you very much, Mr. Chairman, Representative Geren, members of the Subcommittee, and my colleague, Harold Varmus, for letting me go first. I greatly appreciate this opportunity to testify on this issue that so directly affects the future of the Nation, the advanced education and training of scientists and engineers.

As NSF director and as former, and, I very much hope, future professor of physics, I have both a personal and a professional interest in this issue. I make it a point when I visit campuses around

the country as I often do to always seek out graduate students, sometimes individually and sometimes in groups, listen to their concerns, talk about how their experiences are going.

I have also encouraged my colleagues at NSF and throughout the community to talk about the difficulties young scientists and engineers encounter as they embark on their careers because this really is a serious matter, but a very complex one, and it is important to understand the people who are closest to having the experiences to help us understand what is going on.

To help spur this discussion, I had the very good fortune of coauthoring with Mary Good, the Undersecretary of Technology at the U.S. Department of Commerce, an article for Science magazine that addressed many of the issues being discussed today, and with your permission, Mr. Chairman, I would like to submit a copy of that article for the record.

Mr. SCHIFF. Without objection, it will be made part of the record.

Dr. LANE. Thank you, Mr. Chairman.

The COSEPUP report, "Reshaping the Graduate Education of Scientists and Engineers," makes it clear that the current situation presents us with a real paradox. There can be no doubt, I believe, about the quality of the U.S. system of graduate education in science and engineering. It continues to attract students and scholars from around the globe, and it gives students the opportunity to learn in the most effective manner possible through direct participation in research at the frontiers of knowledge.

Yet, even with this outstanding training, some of our graduates have found their career prospects uncertain and their frustrations rising. While the overall unemployment rate for scientists and engineers remains well below the national average for all workers, several scientific disciplines report disappointing rates for recent Ph.D.s and many graduates report obtaining only part-time or temporary work.

The unemployment and the underemployment rates vary significantly across fields, with engineers and life scientists generally faring better than physicists, sociologists and geoscientists.

The outlook is not encouraging in many traditional fields, however. When one considers the spending cuts in Federal R&D spending, the ongoing restructure of industrial R&D and the uncertain future of our national labs, it is likely that the situation will get worse before it gets any better.

It is important for all of us to step back and appreciate the full significance of this perplexing paradox. When we talk about the education and training of scientists and engineers, our conversation, by definition, extends to the very future of the Nation. Today, America's scientists and engineers routinely generate inventions, insights, and breakthroughs that make the country more productive at work, help rid us of deadly diseases, address pressing societal concerns, and build promise for the future.

Just two weeks ago, several newspapers reported on the discovery by a theoretical computer scientist of what is being called a molecular computer, a computational device that taps the precision and predictability of DNA replication to solve a very difficult computational problem. Someday down the road it may become commonplace to find supercomputers in test tubes performing billions

of calculations simultaneously, one example of why all of us should be very concerned if careers in science begin to lose their luster and their attraction for our best and brightest.

We find other examples just by reviewing the issues that top the agenda here in Congress: telecommunications, health care, clean water and other environmental issues, and economic competitiveness, as Chairman Walker discussed in a recent meeting with the National Science Board.

All are issues steeped in science and technology. Science and technology have pervaded, touched, and improved virtually every part of our lives from the wrinkle-free fabrics on our backs to the phones in our cars. Therefore, the very notion that education and training in science and engineering might be viewed as limiting one's career options instead of expanding them must give us pause.

Thanks to the COSEPUP report and other reports on the issue a consensus for action has begun to emerge. The COSEPUP report frequently states that we are facing more than just a temporary slowdown in science and engineering employment.

To quote from the report, "The end of the Cold War," the rapid growth of international competition in technology-based industries, and a variety of constraints on research spending have altered our market for scientists and engineers. The increasing rate of change suggests a need for scientists and engineers who can readily adapt to continuing changes.

In addition to the COSEPUP report, other studies and reports have heightened our awareness and highlighted the need for action. Several recent articles and reports have chronicled the disappointment and disillusionment many young scientists and engineers encounter when searching for permanent employment.

The National Science Board, at its June meeting, concerned about this issue, established the task force on graduate and postdoctoral education. The task force will review the COSEPUP report and other recent studies and will examine many aspects of NSF's role in graduate education, including the balance between fellowships, traineeships, and research assistantships.

At the present time, NSF supports only about five percent in a given year of all the science and engineering graduate students studying in the United States. This fraction varies by field. Just to give you an example, NSF supports something over ten percent of the graduate students in the physical and Earth sciences.

The task force was expected to complete its report and present recommendation before the end of the calendar year. This work and the current wealth of information available for review will enable NSF and the National Science Board to consider new policy and program options for the Foundation.

Again, Mr. Chairman, with your permission, I would like to submit the task force's charge for the record.

Mr. SCHIFF. Without objection, it will be admitted.

Dr. LANE. NSF has also recently taken a number of significant steps to improve opportunities for graduate students and young scientists and engineers. A program we call GOALI, Grant Opportunities for Academic Liaison with Industry, enables graduate students and faculty to gain experience working in industrial settings. A program we call CAREER, which stands for Faculty Early Career

Development, encourages junior faculty to explicitly link their teaching activities with their research responsibilities.

NSF supports several centers programs, engineering research centers, supercomputer centers, science and technology centers, programs which have expanded the learning environment on many campuses by providing a structure for industry-university cooperation and bringing together researchers from different disciplines who are often working on complex problems that cross those disciplinary lines.

In addition, NSF's directorate for mathematical and physical sciences just last month hosted a workshop on graduate and postdoctoral training that attracted great interest from industry and the academic community. The tentative findings from the workshop closely parallel those in the COSEPUP report.

Among the concerns it raised is the narrowness and overspecialization of doctoral training, the lengthening of the time required to obtain a Ph.D., and the low participation rates of women and minorities in science and engineering.

I would like to emphasize, Mr. Chairman, that this latter issue is a very real issue. We know from demographic shifts going on in the country that if our Nation in fact is going to be a leader in science and technology in the 21st century, it is going to be essential that we continue to press on this vital issue of underrepresentation.

Before closing, I would like to emphasize that NSF recognizes the need to work very closely with universities when contemplating changes to current policies. Many academic departments have already begun to redesign their degree programs in light of current concerns, providing more opportunities for group research and interdisciplinary research to better prepare students for careers outside academe.

The National Science Foundation encourages and supports these important efforts on the part of institutions to respond to the changing science and technology scene in the U.S. and to assure better career opportunities for their graduates.

Mr. Chairman, I would like to conclude my testimony with an admonition. We must take great care in framing the questions that lead us to understanding the breadth and the depth of this complex issue. The issue at stake is not simply whether there will be enough faculty openings for tomorrow's Ph.D.s but rather why has a society so broadly based in science and technology managed to define so narrowly the roles and responsibilities of scientists and engineers in its midst?

Only in this way can we best determine how to expand the horizons for young scientists and engineers and at the same time ensure that our Nation possesses the scientific human capital needed for the 21st century.

Above all else, we must move beyond the notion that science and engineering are esoteric and separate when in fact they are universal and pervasive. We must be more aggressive in portraying training in science and engineering as preparing for a broad array of professional careers.

Research experience teaches the path of critical thinking in a way that no other experience can do as a vehicle for informed judg-

ment. We live in a world where informed judgment seems to be in short supply.

We should encourage our students to broaden their understanding and expectations of the diverse usefulness of their knowledge. A study of science and engineering arms students with the knowledge and skills to be captains of industry, leaders of government, editors of newspapers, film producers, or teachers, to name a few possibilities.

Let's not keep that a secret, and let's help our students achieve those noble career goals.

I would like to applaud the Subcommittee for taking up this important matter and thank you for giving me the opportunity to appear here this morning. I look forward to your questions.

[The prepared statement of Dr. Lane follows:]

Testimony of
Dr. Neal F. Lane
Director
National Science Foundation

Subcommittee on Basic Research
Committee on Science
U.S. House of Representatives

Graduate Education in Science and Engineering

July 13, 1995

Mr. Chairman, Rep. Geren, members of the subcommittee, I greatly appreciate this opportunity to testify on this issue that so directly affects our future well-being and continued progress as a nation -- the advanced education and training of scientists and engineers.

As NSF Director and as a former (and hopefully future) professor of physics, I have both a personal and a professional interest in this issue. I make it a point to meet with graduate students and young faculty and listen to their concerns whenever I visit university campuses. I also have encouraged my colleagues at NSF and throughout the community to discuss the difficulties young scientists and engineers encounter as they embark on their careers. To help spur this discussion, I had the good fortune last fall of being able to co-author with Mary Good, the Undersecretary for Technology at the U.S. Department of Commerce, an article for Science magazine that addressed many of the issues being discussed today. With your permission, Mr. Chairman, I would like to submit a copy of that article for the record.

The report, "Reshaping the Graduate Education of Scientists and Engineers," issued by the National Academy of Sciences' Committee on Science, Engineering, and Public Policy (COSEPUP) makes clear that the current

situation presents us with a perplexing paradox. There can be no doubt as to the quality of the U.S. system of graduate education in science and engineering. It continues to attract students and scholars from around the globe, and it gives students the opportunity to learn in the most effective manner possible -- through direct participation in research at the frontiers of knowledge.

Yet even with this outstanding training, some of our graduates have found their career prospects uncertain and their frustrations rising. While the overall unemployment rate for scientists and engineers remains far below the national average for all workers, several scientific societies report high rates for recent Ph.D.s, and many graduates report obtaining only part-time or temporary work.[1] The unemployment and underemployment rates do vary significantly across fields, with engineers and life scientists generally faring better than physicists, sociologists, and geoscientists.[2] The outlook is not encouraging in many traditional fields, however. When one considers the pending cuts in Federal R&D spending, the ongoing restructuring of industrial R&D, and the uncertain future of our national labs, it is easy to imagine the situation getting worse before it gets any better.

It is important for all of us to step back and appreciate the full significance of this perplexing paradox. When we talk about the education and training of scientists and engineers, our conversation by definition extends to our future as a nation. Today, America's scientists and engineers routinely generate inventions, insights, and breakthroughs that make the country more productive at work, help rid us of deadly diseases, generate new technologies for industry, improve our environment, address pressing societal concerns, and build promise for our

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[1] Reported in recent (1994-1995) issues of *CPST Comments* (formerly *Manpower Comments*), published by the Commission on Professionals in Science and Technology, Washington, DC.
[2] National Science Foundation, Division of Science Resources Studies, Data Brief: "For 1993, Doctoral Scientists and Engineers Report 1.6 Percent Unemployment Rate But 4.3 Percent Underemployment," March 15, 1995.

future. Just two weeks ago, several newspapers reported on the development of what is being called a molecular computer -- a computational device that taps the precision and predictability of DNA replication. Someday down the road, it might become commonplace to find supercomputers in test-tubes performing billions of calculations simultaneously.

This is just one example of why all of us should be very concerned if careers in science begin to lose their luster and attraction for our best and brightest. We find other examples just by reviewing the issues that top the agenda here in the Congress: telecommunications, health care, clean water and other environmental issues, and economic competitiveness, as Chairman Walker discussed in a recent meeting with the National Science Board. All are issues steeped in science and technology. Science and technology have pervaded, touched, and improved virtually every part of our lives, from the wrinkle-free fabrics on our backs to the phones in our cars. Therefore, the very notion that education and training in science and engineering might be viewed as limiting one's career options instead of expanding them must give us pause.

Thanks to the COSEPUP report and other reports on this issue, a consensus for action has begun to emerge. The COSEPUP report frequently states that we are facing more than just a temporary slowdown in science and engineering employment. To quote from the report, (quote) "the end of the cold war, the rapid growth of international competition in technology-based industries, and a variety of constraints on research spending have altered our market for scientists and engineers....The increasing rate of change suggests a need for scientists and engineers who can readily adapt to continuing changes."[3] (end quote)

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[3] National Academy of Sciences, Committee on Science, Engineering, and Public Policy, *Reshaping the Graduate Education of Scientists and Engineers,* National Academy Press, 1995, page 2.

In addition to the COSEPUP report, other studies and reports have heightened our awareness and highlighted the need for action. A paper issued last month by the RAND Corporation and Stanford University has attracted attention by concluding that the higher education system is currently overproducing science and engineering Ph.D.s.[4] Several recent articles and reports have chronicled the disappointment and disillusionment many young scientists and engineers encounter when searching for permanent employment.[5]

The Science Board at its June meeting established the Task Force on Graduate and Postdoctoral Education. The Task Force will review the COSEPUP report and other recent studies, and it will examine many aspects of NSF's role in graduate education, including the balance between fellowships, traineeships, and research assistantships. The Task Force is expected to complete its report and present recommendations before the end of this calendar year. This work and the current wealth of information available for review will enable NSF and the National Science Board to consider new policy and program options for the Foundation. Again, with your permission Mr. Chairman, I would like to submit the Task Force's charge for the record.

NSF has also recently taken a number of significant steps to improve opportunities for graduate students and young scientists and engineers. The GOALI program (Grant Opportunities for Academic Liaison with Industry) enables graduate students to gain experience working in industrial settings. The CAREER program (Faculty Early Career Development) encourages junior faculty

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[4] William F. Massy, Charles A. Goldman, *The Production and Utilization of Science and Engineering Doctorates in the United States,* Stanford University, Institute for Higher Education Research, 1995. Discussed in: Daniel S. Greenberg, "So Many PhDs," *The Washington Post,* July 2, 1995, page C7.

[5] Sheila Tobias, Daryl Chubin, Kevin Aylesworth, *Rethinking Science as a Career: Perceptions and Realities from the Physical Sciences*, Research Corporation, 1995 (forthcoming). James C. Fleet, "Young Researchers' Disillusionment Bodes Ill for the Future of Science, *The Scientist,* May 29, 1995, page 11. Sharon Begley, "No Ph.D.s Need Apply," *Newsweek,* December 5, 1994, pages 62-63.

to link their teaching and research responsibilities. NSF's several centers programs, including the Engineering Research Centers, Supercomputer Centers, and the Science and Technology Centers, have expanded the learning environment on many campuses by providing a structure for industry/university cooperation and by bringing together researchers from different disciplines.

In addition, NSF's Directorate for Mathematical and Physical Sciences just last month hosted a workshop on graduate and postdoctoral training that attracted great interest from industry and the academic community. The tentative findings from the workshop (which I should note do not necessarily represent current NSF policy) closely parallel those in the COSEPUP report. Among the concerns it raised were the narrowness and overspecialization of doctoral training, the lengthening of the time required to obtain a Ph.D., and the low participation rates for women and minorities in science and engineering.

Before closing, Mr. Chairman, I want to emphasize that NSF recognizes the need to work in very close cooperation with universities when contemplating changes to current policies. Many academic departments have already begun to redesign their degree programs in light of current concerns, providing more opportunities for group research and interdisciplinary research to better prepare students for careers outside academe. Furthermore, the Federal role in graduate education is limited. Only 20% of graduate students in the sciences and engineering report receive Federal support in a given year. Even this figure can be misleading because it reflects a broad range according to discipline, from about 6 percent in the social sciences to over 36 percent in the physical sciences. (NSF provides support to about 12 percent of graduate students in the physical sciences and earth sciences, but overall only about 4 percent of <u>all</u> science and engineering graduate students receive NSF support in a given year.) The preponderance of student support in all scientific disciplines is provided from institutional sources or by the students themselves. Federal

agencies should support research and related graduate education according to their respective missions, while providing universities and colleges with encouragement and flexibility to offer students a broad array of learning experiences.

I would like to conclude my testimony with an admonition. We must take great care to frame the questions that lead us to understanding the breadth and depth of this complex issue. The issue at stake is not simply whether there will be enough faculty openings for tomorrow's Ph.D.s, but rather why has a society so broadly based in science and technology managed to define so narrowly the role and responsibilities of scientists and engineers within its midst. Only in this way can we best determine how to expand the horizons for young scientists and engineers and, at the same time, ensure that our nation possesses the scientific human capital needed for the 21st Century .

Above all else, we must move beyond the notion that science and engineering are esoteric and separate, when in fact they are universal and pervasive. We must be more aggressive and creative to portray training in science as preparation for a broad array of professional careers. Research experience teaches us the patlı of critical thinking -- a vehicle for informed judgment. We live in a world where informed judgment seems to be in short supply.

We should encourage our students to broaden their understanding and expectations of the diverse usefulness of their knowledge. After all, science and engineering undergird the fundamental elements on which much of contemporary society is built. The study of science and engineering arms students with the knowledge and skills to be captains of industry, leaders in government, editors of newspapers, film producers, or teachers to name a few possibilities. Let's not keep that a secret! And, let's help them achieve these noble career goals.

Instead of expecting all of our graduate students to replicate their mentors, we should educate them to the myriad opportunities that education and training in science offers. And we should instill in them a sense of responsibility for the larger society. Does this happen? Of course it does, but perhaps not as often or as visibly as would be ideal.

The noted historian, Jacob Bronowski, wrote in his seminal work, *The Ascent of Man*, (quote) "The world today is made, it is powered by science." (end quote) If his observation is correct, and I think it is, then the usefulness of education and training in research is limited only by a person's imagination, not by the society in which he or she lives. All of us in government, in industry, and in the universities have a responsibility to articulate this philosophy.

I would like to applaud the subcommittee for taking up this important matter and for giving me the opportunity to appear this morning. I will be happy to answer any questions.

Mr. SCHIFF. Thank you, Dr. Lane. It is also a pleasure to have you in front of us here at the Subcommittee.

Dr. Varmus?

STATEMENT OF DR. HAROLD VARMUS, DIRECTOR, NATIONAL INSTITUTES OF HEALTH

Dr. VARMUS. Mr. Chairman, members of the Subcommittee, I want to thank you again for paying attention to this important topic. In view of the fact that you submitted my written remarks for the record, I will speak extremely briefly and allow us to get on with the questions and answers. I will summarize the highlights of my responses.

Let me say first that I speak to these issues based upon 20 years of experience as a professor at the University of California, San Francisco, where I was involved in all aspects of graduate training and, of course, based on 20 months as the director of the NIH, an agency which is responsible for roughly one-third of all the health research done in this country and for the renewal of the human resources required to carry out that research.

NIH has a diversity of training programs. We spend well over $400 million a year on the training of postdoctoral and predoctoral students. Roughly 6,000 of the students who are supported on our programs are in what are called institutional training grants. There are roughly 1,600 of these around the country. They are all peer-reviewed, and the training grants are awarded to institutions based on grant applications made by the faculty who are responsible for directing those programs.

In addition, we support about 10,000 students as research associates on our research project grants.

Finally, we have roughly 600 students who are supported on individual fellowships and about 800 who are studying both the M.D. and the Ph.D. degrees. In total, we support roughly 15 percent of students who are in biomedical research training programs, and those 15 percent, we know from our evaluations, to be among the most successful trainees.

Overall, we believe our programs have provided our country with a very highly trained cadre of investigators who go on to hold NIH grants, who are responsible for American leadership in biomedical research and for the remarkable productivity of biomedical investigation over the last several years.

Our training grant programs, in particular, have been singled out by many, including the COSEPUP report under discussion today, as models for carrying out graduate training.

Nevertheless, the report and this hearing are particularly welcome because biomedical research is having difficulties. We are undergoing a transition from a prolonged state of growth to a steady state, and in that transition there is difficultly. There is difficulty in obtaining academic jobs, difficulty in obtaining research grants in some areas, even the most productive biomedical research. As few as five or ten percent of new grant applicants are successful in the grant review process. These low rates of success have created a high level of anxiety among both graduate and postgraduate trainees, and in some sense this is exacerbated by, but also compensated by, the change in the demographics of employment.

That is, the employment profile has changed, with decreased numbers going into academic positions, roughly a twofold increase in the various industrial sectors, the pharmaceutical industry, the biotechnology industry, research resources industries. And there has been an increased employment in so-called nontraditional occupations, including patent law, entrepreneurial ventures, science writing, science education, and so forth.

I and the NIH agree with many of the conclusions of the COSEPUP report. We agree, in particular, with the need to increase information and guidance about career choices and the need to break down the stereotypes that currently exist in many of our graduate programs about what the products of our training programs should be like.

We agree with the need to try to shorten the time to degree in our graduate programs.

We also agree it is not a time to decrease the number of students in our graduate programs, even if NIH could control the numbers, which of course we can't. We consult with the National Research Council every four years to ask about the numbers of students who should be in the various biomedical and behavioral research programs, and we need to be guided by that advice.

I would point out that our ability to implement some of the suggestions made in the COSEPUP report are abetted by the nature of the NIH training grant program that supports many of our students. We have in the past, for example, asked those programs to carry out instruction in the conduct of science the way in which authorship is accredited and the way in which students respond to suggestions of scientific misconduct.

In the context of that kind of direction, we are in the process of considering asking those programs to broaden the existing training in the conduct of science to include better career guidance.

We are also in a position to watch the outcomes of the training programs with respect to the time it takes to achieve a degree and the employment outcomes that result from training by the programs to which we give awards.

In conclusion, I appreciate the chance to present these views briefly, and I welcome your questions.

Thank you very much.

[The prepared statement of Dr. Varmus follows:]

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

National Institutes of Health
Bethesda, Maryland 20892

For Release Upon Delivery

Statement of

Harold Varmus, M.D.

Director

National Institutes of Health

on

The National Academy of Sciences Report:

"Reshaping the Graduate Education

of

Scientists and Engineers"

Before the

Subcommittee on Basic Research

House Committee on Science

July 13, 1995

Mr Chairman and Members of the Subcommittee:

I am Harold Varmus, Director of the National Institutes of Health. I am pleased to appear before you to discuss my views of graduate training, especially in fields related to biomedical sciences, and to respond to the report from the National Academy of Sciences, summarized by Dr Griffiths.

My opinions in this area are based on two realms of experience For over 20 years, I was a member of the basic science faculty at the University of California, San Francisco, School of Medicine and directly involved in all aspects of graduate training. Now, for about 20 months, I have been responsible for a Federal agency that pays for a substantial fraction of the Nation's health-related research and has a deep commitment to the training of new investigators in the relevant fields of science.

The sciences we support are in a period of remarkable productivity, and in some ways they are less acutely affected by the problems you are addressing here today (For example, the recently published report from the Rand Corporation singles out "bioscience" as the only field judged not to have an overproduction of Ph.D. recipients.)

Still, there is considerable and justifiable anxiety among students currently enrolled in, and those recently graduated from, Ph.D. programs in biomedical and behavioral sciences. NIH-supported programs have grown dramatically from the end of World War II until the recent past, but during the last few years we have been making a painful transition to a steady state enterprise.

There are many reasons for this, but the relevant consequences have been heightened competition for fewer jobs, especially in the academic sector; a lower likelihood of success when applying for NIH grants (in certain fields, as few as 5-10 percent of applicants for new grants are

successful); longer periods of graduate and post-doctoral training; and widespread concerns about the long-term productivity and career prospects of even the best students in whom major educational investments have been made.

These problems have been somewhat offset by the growth of employment in medical research industries---including biotechnology, research supplies, and pharmaceutical companies. These industries are now hiring about twice as large a proportion of graduates in our fields as they did fifteen years ago. In addition, recent advances in biomedical science are now affecting American society in many important ways. As a result, our graduates are finding employment in "non-traditional" occupations---patent law, science policy and administration, the media, investment firms, and novel educational settings.

The primary goal of the support that NIH provides for graduate training is to produce new, highly-qualified investigators who are likely to perform research that will benefit the Nation's health. We attempt to achieve this goal through a variety of grant mechanisms. About 6,000 NIH-supported students are enrolled in Ph D programs funded largely by NIH training grants These grants are awarded to the host institution only after careful peer-review of a grant application from the faculty who run the program. Training grants generally support students for about two or three years, after which time the students are often paid as research assistants on research project grants; about 10,000 graduate students currently are receiving such support. Other students (about 600) receive individual graduate training awards from the NIH In addition, the Medical Scientist Training Program (MSTP) supports over 800 students who are pursuing both the M D and Ph.D degrees at 33 medical schools

Through these various mechanisms, NIH is involved in the training of about 15-20 percent

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of the students enrolled in Ph.D programs in biomedical sciences (Foreign students are supported only as research assistants on research project grants, not on institutional training grants) Thus we have a substantial impact on the production of new generations of Ph.D. recipients, but we cannot control the overall numbers of students, even if it were appropriate to do so We have reason to believe that we support many of the most promising students in the fields of health research; for example, our studies show that NIH trainees are relatively successful when they apply for research grants and jobs. In fact, training programs whose graduates are not successful are unlikely to be renewed when they are again subjected to peer review. In my opinion, any retreat from our traditional support of graduate training would be a mistake; it would send an inappropriately negative signal to the best students at a time when biomedical research is flourishing on many fronts. This view has been repeatedly reinforced by the NRC's quadrennial analyses of graduate education in biomedical and behavior sciences, most recently in 1994

Although our primary purpose is the training of new, independent NIH-supported investigators, we strongly support the recommendation of Dr. Griffiths' Committee that graduate programs should explain and endorse the diversity of career options in scientific fields, including biomedicine The enthusiasm of students is sustained by the prospect of reasonable job opportunities, and the vitality of scientific fields increasingly depends on the work of well-trained Ph.D recipients who enter non-traditional (i.e., non-academic) positions. All students should therefore be provided with information about such jobs I believe these changes in attitude can be achieved in the programs we support without any appreciable erosion of the research experience that remains the cornerstone of graduate training.

We are prepared to consider ways to guarantee such changes---for example, by mandating

that they be part of institutional NIH training programs Our ability to do this has been demonstrated recently by the willingness of the faculty, who receive our nearly 1600 training grants, to comply with a requirement for instruction in the responsible conduct of research. The courses that are now in place to teach students and post-doctoral fellows about conflicts of interest, responsible authorship and data management, and policies for handling misconduct and protecting research subjects could be expanded to address new career options. Many institutions that receive training grants have expanded their courses to include all graduate students, not just those supported by the NIH In this way, training grants can improve the educational opportunities and career guidance for all students at institutions that receive NIH funding.

I also share the COSEPUP report's concern about the increasing length of graduate training. From my own experience as a faculty member, I have learned that lengthy training periods are generally attributable to students who are poorly prepared or poorly motivated for graduate work or to faculty who provide inadequate mentoring to their students. Studies have shown that even a short period of support on an NIH training grant reduces a student's time to degree This suggests that peer review identifies the programs with those students and faculty likely to function effectively in the training process By giving greater attention to the quality of graduate education and the selection of appropriate students, I believe it is possible to decrease the length of Ph D. programs without undermining the seriousness of the thesis research project

Despite the problems that the NAS Committee has identified, there is no doubt that our Nation has been successful in the training of new scientists and that the Federal government has had an important role in this success The need for research in the health sciences is unlikely to

diminish in the decades ahead. Our ability to harvest the benefits of recent scientific progress and to compete in the international arena will depend on the continued excellence of our graduate programs and the commitment of agencies, such as the NIH, to their support. It is nevertheless important to examine graduate education critically from time to time, and I appreciate the opportunity to discuss this report with you today.

Mr. Chairman, I would be glad to answer any questions that you or other Members of the Subcommittee might have.

Mr. SCHIFF. Thank you, Dr. Varmus. It is a pleasure to have you here also. We will proceed again under the five-minute rule.

I want to say, first of all, earlier I made a little jest about the fact that the National Science Foundation is under the authorizing jurisdiction of the Subcommittee. The National Institutes for Health is not. I want to say that if I had a magic wand that determined jurisdiction, that would change. The National Institutes of Health would also be under the Basic Research Subcommittee.

Now, some people fight to the death over jurisdiction around this place. I am not looking forward to that happening in the near future.

But the reason I support that idea is, as I look at medical science, it is more and more tied into developments in technology ranging from, as a patient at times when I have sought medical treatment and constantly hooked up to different machines, to the fact that there are things which fortunately I have not needed, from laser therapy to the use of televised screens which show a specialist far away from the patient and the practitioner what is going on, an EKG or EEG, whatever it might be.

So I see these two growing so closely together that I think perhaps they should be under the same jurisdiction somewhere.

Having said that, if either of you wish to respond on that, I would be most happy to hear you.

[Laughter.]

Mr. SCHIFF. If you wish to plead the Fifth, that would be okay, too.

Dr. VARMUS. I am going to defer a response to the question of authorization, but I would echo one aspect of the comment that you made. That is that biomedical research is no longer narrowly defined as biology. We have in the ranks of those who do research that is relevant to health many computer scientists, many engineers doing bioengineering, many chemists who are involved in the development of pharmaceuticals. Structural biology is increasingly dependent upon computers in various physical sciences. So that we recognize a very wide spectrum of scientific groundings that lead to research in the health sciences. We believe the health sciences in general are very accepting of scientists who have been trained in a broad variety of disciplines.

I suppose one way to connect this with the COSEPUP report is to point out that we think it is important that students who are being trained in these other sciences recognize opportunities that exist to use what they have learned in fields that may not seem immediately medical in the development of health information.

Mr. SCHIFF. Dr. Lane?

Dr. LANE. Mr. Chairman, very briefly, the example that I used in my testimony was an example of the theoretical computer scientist who I don't think had any particular knowledge of biology, genetic research, but decided to spend a year in a laboratory trying to learn something about it, and obviously richly benefited from the science and the scientists in that laboratory.

We need to see much more of that happening. That is done better to the extent that our two agencies cooperate, which I think we do very well. And on the campuses, the researchers cooperate and

have the flexibility to do that. We intend to increase our support of those kinds of interdisciplinary activities.

Mr. SCHIFF. I have used about half my time and have a request by Mr. Boehlert to go out of order. So, to do this fairly, I am going to yield to you the balance of my five minutes here.

Mr. BOEHLERT. Thank you. I apologize for making that special request, but I have another commitment, as is so often the case.

Let me ask both of you, Dr. Griffiths said in his testimony that there is no central way to control the number of graduate students. But, of course, there is. Both of you give a lot of money out in research assistantships and fellowships. They have a large impact on the number of graduate students. Do we need to look more closely at whether or not NSF and NIH are funding too many graduate students?

Dr. LANE. Well, Mr Boehlert, one reason that I commented on the fact that NSF supports roughly five percent of the science and engineering graduate students across the country, while we have not run experiment, my guess would be that if we were to decide to reduce that to four percent, it would not have a large effect on the overall national problem.

My guess is though it is a little presumptuous to say so that we would end up cutting back on some of the strongest and most capable and probably ultimately most successful scientists and engineers during those critical years.

But we are very concerned about the time to degree. We could, of course, just limit the number of years. I spoke of the number of years. But we could also limit the number of years that we provide support, as is done in the U.K., for example. That takes a good bit of flexibility out of the system and makes it difficult then to address a number of the issues that Dr. Griffiths talked about in his testimony.

So we have chosen instead to give the researchers the flexibility to optimize the research educational activities going on in the laboratories, but these are issues we continue to discuss with our task force I mentioned earlier.

Dr. VARMUS. I would answer in a somewhat similar way. We are responsible for funding a relatively small proportion of those students who are currently in programs in biomedical and behavioral sciences, and we can't control the numbers ourselves.

We also have evidence to believe that the students who are beneficiaries of our support are in fact among the most successful. We look at the science that is being done by the graduates of our programs. The science is extremely productive at the moment, and we would not want to give a signal that we believe that the science in the scientific area is in retreat.

We would argue we know that there is difficulty in employment at the moment and we would rather try to diversify the employment opportunities in ways that are suggested in the COSEPUP report than retreat on that matter.

Mr. SCHIFF. I would have to say that my time has now expired, but I give myself another two minutes and extend it to Mr. Boehlert.

Mr. BOEHLERT. The Chair is very generous.

You know, getting back to my colleague's comment earlier about slave labor, we hear complaints all the time from industry and from students that the research assistantships program funding the grad students, what really happens is that the faculty research sort of takes precedence over the education of the students. How do you guys address that?

Dr. VARMUS. One way we do that is the training grants, the training grant system, what is evaluated is the nature of the training program itself. The peer review committee looks at the program that the faculty has established for student support. If the peer review group judges that the faculty are not providing an adequately broad and supportive training program, the student's need to be sacrificed to the faculty ambitions, that program will succeed less.

Mr. BOEHLERT. So the training grants are separate from the research assistantships?

Dr. VARMUS. That's correct.

Mr. BOEHLERT. What is the trend? Training grants are going up, research assistantships are going down?

Dr. VARMUS. It's about the same. But let me point out that most of the students trained by NIH are on training grants for perhaps two or three years. During the first couple of years of training, when they are receiving their course work and they enter an individual research laboratory, then they tend to become supported by project grants as research associates. So students may receive both at different times in their training.

Mr. BOEHLERT. It would seem to me, one, you are recognizing that there is some legitimacy to this complaint from the students.

Dr. VARMUS. Yes, and we are concerned about that. As Neal mentioned, the number of years that the student spends in the training programs, we know that the length of training involved in the sciences has increased. It tends to be less long to degree for students who have been supported by NIH training programs, which would suggest that we are tending to award grants to those programs that have been most expeditious in getting their students through the programs.

Mr. BOEHLERT. Dr. Lane, and I know my time will be up, but you should be able to respond to this.

Mr. SCHIFF. Briefly, if you would, Dr. Lane.

Dr. LANE. Briefly, we also have graduate fellowships that are awards made directly to the student. So the student then has a complete choice of where he or she works and for whom. That is another mechanism whereby we can provide this.

I must add that my own experience in the university is such that at least as many times as I thought a professor was hanging onto a student too long, I saw situations where you not get the student out the door.

There are a variety of reasons for that. These can be very strong students. So I am not suggesting that we have weak students in the graduate program that I am referring to. But it is sometimes difficult on that side as well.

Mr. BOEHLERT. Thank you.

Thank you for your indulgence, Mr. Chairman, and I thank my colleagues for their consideration.

Mr. SCHIFF. Mr. Geren?

Mr. GEREN. Thank you, Mr. Chairman.

Dr. Lane, you mentioned the NSF supports about five percent of the graduate students. Do you have any feel for how that would break down between masters and Ph.D.s?

Dr. LANE. Mr. Geren, I really don't have a feeling about that. I have the thought in my mind, but I think that our colleagues who have analyzed the data have had difficulty with this as well, and the problem is that in so many of these fields the masters degree really is in many fields of science as opposed to engineering, the masters degree really has been traditionally a step along the way to the Ph.D. So you would almost have to count, well, how many students are you supporting who passed their qualifiers and are clearly now on the Ph.D. track, and I don't know the answer to that.

Mr. GEREN. Dr. Lane, do you endorse the NAS report recommendation to increase the use of traineeships in the support of graduate students? I guess I would ask you to comment on how you would consider it from the students' perspective and the research perspective and the relative value of graduate research assistantships and traineeships and fellowships. Where should the emphasis be?

Dr. LANE. It is a difficult question, and it is one that this task force is looking very hard at. So I am anxious to have the findings of that task force.

Each of these modes in the way NSF supports graduate students has its benefits. The graduate fellowship gives the student the most flexibility and is probably the most competitive from the student's point of view.

The NSF traineeships are provided to departments and institutions and it enables a department to do something that is thought to be particularly important, usually in integrating research and education in a somewhat novel way or interacting with industry.

Then the third one, the research assistantships, are provided through the research grant, and they have the advantage that it enables the faculty member, the research director of the project, to best match the student's capability with the research that is being done.

We are looking at the mix. There may be a need for a shift in the mix, as COSEPUP suggests. That is why the study is going on.

Mr. GEREN. Mr. Chairman, in light of the vote coming up, I yield back the balance of my time.

Mr. SCHIFF. I think we will proceed to the second bell. It will give us another five minutes here. If members could be brief, I would appreciate it and we can get in as much as we can.

Mrs. Morella?

Mrs. MORELLA. Thank you very much.

Thank you, Dr. Lane, Dr. Varmus.

You know, Robert Frost once defined a poem. He said it is something that begins in the light and ends in wisdom and by defining wisdom, it tells me something I didn't know I knew.

Now, in the case about the report, is this new stuff like I didn't know I knew it, or you knew it all the time? Because as I look at it, I can sort of say, well, I appreciate their doing this report, but certainly I know that we need to do more with regard to limiting

the time of graduate education, certainly I feel we need to do more with getting people, other people experiences to demonstrate to them other career opportunities.

Would you like to comment on that briefly?

Dr. VARMUS. All the things, as Dr. Griffiths mentioned, all the things that are in the report are being done at one institution or another. Certainly, at my former institution, the University of California at San Francisco, we were very concerned about the growth in time to degree. We were recognizing that our students were becoming more interested in alternative careers, that more students were going into industrial occupations. Many are still going into academic occupations.

I think what the report does is set this out for a broad audience as a change in graduate education and it signals the need for many programs, not just the few that are in the forefront, to adapt to the changes that are in the environment.

Dr. LANE. I would only add that I think since there is so much interest in this topic and so many different things tried and so many different things being said about graduate education, the other thing that is advantageous with the report is that it really does point out that this is a very complex issue. Some things are not so simple here, and that is as a result of a lot of thought being given by people with a great deal of experience. That in itself was helpful, I think where they show us that are no really simple answers.

Mrs. MORELLA. I would be concerned about studies upon studies upon studies, as I know you have got one coming out, you said, at the end of this calendar year. I know you always reevaluate your programs as you should. I would just hope that you wouldn't have an extra study to add to it.

I want to ask Dr. Varmus, excuse me for speaking so quickly because of the time, the concept of the programs you have at NIH that deal with training young people. I know you had a program with Walt Whitman High School where students would come and spend some of their time and try to understand what they liked about medical science and the varied careers.

I have a concern that I have heard that some of the kinds of programs you have with young people, whether they are internships or not, are counted as part of their FTE, their full-time equivalent, which means that you cut them out because you cannot afford the luxury of using these young people as full-time employees. Am I correct, and would you like to comment?

Dr. VARMUS. Summer students are not counted as FTEs, but we do have, for those students who come to our campus to work in temporary employment, they are counted as FTEs. That is a problem for us.

Mrs. MORELLA. It is unfair, isn't it, to the kind of things we are talking about?

Dr. VARMUS. Those are not the kind of outreach programs you are mentioning here. They are not educational programs.

Mrs. MORELLA. But they are programs that could expose them to professionals who might inspire them to go into the scientific fields. Would you like to see that changed?

Dr. VARMUS. Yes.

Mrs. MORELLA. Thank you.

Thank you, Mr. Chairman.

Mr. SCHIFF. Mr. Brown?

Mr. BROWN. Thank you very much, Mr. Chairman.

This is a complex subject, gentlemen and I think the hearing helps to educate us into the awareness of the complexity of it.

Amongst the issues that increase complexity is the large number of foreign-born graduate students in the mix. There is some awareness that we were reaching a level of saturation for the need for Ph.D.s in some of the sciences, physics, for example, as long as 20 years ago. That has been obscured by the increase in graduate students.

I refer to an article and a lot of speeches that Dr. Digby out at Cal Tech has been making. He said that this started 25 years ago. One wonders why we haven't caught up to it.

Dr. Lane, a few years back NSF was criticized for its propensity to predict the need for additional Ph.D.s in many fields, including physics, and that seems to have been a slight exaggeration of the situation and subjected the Foundation to some criticism.

Do you think that that situation has been remedied, that your projections are now fully cognizant of the complexity of the situation and that you are not overpredicting the need for Ph.D.s in any field?

Dr. LANE. Mr. Brown, the paper that you are referring to, I believe, stated that the demographic shifts suggested as a result of the baby bust, fewer young people would be available for careers in science and engineering than in prior years.

But it went on to project the Ph.D. replacement needs would double between the years 1988 and 2006. Based on a number of assumptions, these data were pretty widely interpreted as predictions of a shortage, while there was really no basis to predict a shortage. And certainly we don't at this point feel we have a basis for projecting the demand side.

I think we can continue to do the kind of analysis that we have and try to give all of the agencies and the Congress the information about how many people we think will be coming out of the pipeline. But we don't make any effort to predict demand.

Mr. BROWN. I think that is a sound policy, and of course the solutions that are being suggested here by the report before us as well as what you have indicated would be applicable under a number of different conditions. It is appropriate to do some of these things, regardless, and I commend you for the progress that has been made in that direction.

I will yield back the balance of my time.

Mr. SCHIFF. Thank you, Mr. Brown.

The Subcommittee will stand in recess pending the vote.

I would ask the members to return as quickly as they can so we can resume the hearing.

We will recess for about ten minutes.

[Recess.]

Mr. SCHIFF. I would like to reconvene the Subcommittee, please.

I would like the witnesses to return to the witness table.

I would like to now recognize Mr. Bartlett for questions.

Mr. BARTLETT. Thank you very much.

I just wanted to set the record straight. When I spoke of slave labor, I want the record to be very clear that I did that with respect and admiration. I have been there.

Dr. Lane mentioned the problem that we sometimes have in getting graduate students to complete their degree, and I think those who haven't been down that road don't understand the problem there, and those who haven't been there don't understand the satisfaction and fulfillment that one gets in the search for knowledge.

I think that when a graduate student is having a lot of success and satisfaction and fulfillment, there is a tendency to continue that very fulfilling experience. You know, I understand that, and that is one of the reasons, you know, if the longer time to Ph.D. is that reason, that's not a bad one because it's a very fulfilling, rewarding experience, and having worked in every segment, I think, of the research R&D community, a big part of our new knowledge comes from institutions where these graduate students study.

I just want to make it very clear that I did that with respect and admiration.

Dr. Lane, in your presentation there was a sentence, and I am going to read it, "Why has a society so broadly based in science and technology managed to define so narrowly the role of responsibility of scientists and engineers within its midst?"

I had a very interesting personal experience with that. I worked for one of the really great employers of our country, IBM, for nearly eight years. The thing got straightened out after a while, but when I went there, it was kind of as if they perceived that the mind was a vessel of limited size that if you filled it up with a lot of detailed, focused information, that there wasn't enough room left for common sense for managerial skills, for entrepreneurialship.

So, in effect, it was almost as though they needed to provide you with a guide to find your way to the bathroom because if you were an accomplished scientist, surely you could do little else. I gather that was the kind of problem that you were focused on.

Is that getting better?

Dr. LANE. Mr. Bartlett, I really appreciate your comments. I don't know if it's getting better. That is why I wanted to emphasize the point because I think it is so important.

The way we will get a wider understanding of what this experience is like, the Ph.D. experience, which I view as probably the most extraordinary period of development in a professional scientist's or engineer's life, is a relatively short fraction of the professional lifetime. It is a time where—I don't know if you like the tree model—you are building a whole trunk and the first few branches of that tree. It is an incredibly fulfilling experience, but it is very hard, if you haven't lived through it, to know what we are talking about.

So I think that we must do a much better job of helping people understand the nature of that experience but also the extraordinary resource that is now available to the larger society at the end of that experience.

So, the myth, I think, is that it is a narrowing tunnel somehow that the student barely trickles out the end, unable to do anything because they are so narrowly focused. It is really quite the other

way around. Often the student doesn't understand his or her capability to do so many different kinds of things, and society at large certainly does not understand that. So we have a real job to do.

Mr. BARTLETT. I hope that that gets better understood because I think that the experience of working and being awarded a Ph.D. prepares one for a great deal more than just teaching or research, the initiative, the drive that you need. In fact, there is a dream I understand that only Ph.D. candidates have, and that is the dream that it is late in the semester and that you have forgotten to go to a course.

You are shaking your head. You have had the dream?

[Laughter.]

Mr. BARTLETT. I had a psychologist friend who told me he had done a survey, and only Ph.D. candidates had that. You realize it's too late to catch up on the material and it is past the drop date and you have had it for that course.

Some of you are shaking your heads. It is really both a very stressful and a rewarding experience.

Dr. Varmus, I worked at NIH for three years, and I was the happy recipient of NIH grants, and later on some contracts from NIH, and you have a very admirable system of peer review.

But that nothing is perfect, and one of the problems years ago, and I just wanted to ask you is it still a problem with this peer review system, is that we have some centers that really are preeminent. I was in the respiratory area, and there were several different centers that were preeminent, and the people that graduated from there went on to become part of the peer review committees.

So there was the perception that in this kind of environment, in spite of the best intentions, that the rich got richer and the poor got poorer because those who had turned out good graduates, their graduates ended up on the peer review committees, they really respected those who submitted grants from their alma matters, and with all of the best intentions, there still was kind of a tendency for the rich to get richer and the poor to get poorer.

Do we have a mechanism for making sure that we have a really broadly focused evaluation of these applications?

Dr. VARMUS. We pay a great deal of attention to the composition of our peer review groups. They are balanced with respect to many criteria: age, gender, the part of the country they come from, the discipline.

There is, of course, inevitably criticism because many of our grant applicants are not successful, and one of the ways that one complains about the lack of success is to say it's either an old-boys' network or "I don't recognize the names of anybody on the committee."

So, it can work both ways. We need to have people on the committee who have demonstrated excellence, and one way to demonstrate excellence is the peer review panel member has already shown his ability to win the esteem of his peers by obtaining a grant through the system.

Most of our evaluators have been successful in the peer process. We don't believe, through the close examination we have made of our panels, that they represent an in-group or simply an old-boys' network.

Mr. BARTLETT. I just want to make one comment. Thank you very much. And that is that we are pretty lucky in the area that you all are here representing the area that this Committee represents, and that is in a shrinking budget environment there is a major focus of this committee on basic research and the core missions of the institutions that it is our privilege to represent here.

I am pleased that the budget is up on several of these areas, in spite of an overall shrinking budget.

Thank you very much.

Thank you, Mr. Chairman.

Mr. SCHIFF. Thank you, Mr. Bartlett.

Ms. Lofgren?

Ms. LOFGREN. Thank you, Mr. Chairman.

I would just note for Mr. Bartlett's comment that even those who are not pursuing Ph.D.s in science have the dream where you wake up, you have forgotten that you were in the course and you further have forgotten the classroom where the test is being given. I can recall that very well from my undergraduate days.

You know, I was thinking about where we need to go as a country, and I am really referencing my questions to the prior panel. You recall last year or the year before last, actually, our county, Santa Clara County, did a strategic plan for the future. One of the volunteers who helped us quoted Wayne Gretzky. He said strategic planning is skating to where the puck is going to be. And we are talking today about a problem in employment of Ph.D.s, but we also need to look ahead to where the puck is going to be in 15 years.

I think that is a complex mix of, I am sure, more than I know, but the role of foreign students is in that mix, the role of remuneration for those who go into science and engineering is in that mix. And I also think our ability to attract non-white men—I don't want again to fight—is also in that mix.

Caucasian boys are like 20 percent of the fifth grade class in Santa Clara County, and if we look ahead 15 years to where are we going to get the rocket scientists of the future, we have to look at the fifth grade and see that most of the fifth-graders are women and ethnic minorities, and we have not done as good a job in this country of attracting them to those fields.

I am wondering, the thing about, for example, Singapore, that 20 years ago had piecework as an employment base and went forward with the intent to be prosperous based on a knowledge-based economy, and succeeded. What we might do, thinking strategically, and whether your agencies would lead in this, to map out a plan, a multifaceted plan that could help us be successful in 15 years by maintaining really top-flight science and engineering, not just grants but looking at remuneration for scientists.

Should we take a look at the role of patent law, what kind of remuneration goes to graduate students?

And I have a concern, if you go into Silicon Valley, you will find in terms of the creative minds in those industries, a U.N. That is wonderful. I am not concerned about that. But increasingly, and this is just the beginning, it may not reflect a trend, some of the really top-notch scientists from India are starting to go home. Some of the top-notch scientists from Taiwan are starting to go home.

Now, if that happens, and we are not nurturing our fifth grade today, where are we as a country? Maybe we should take a look at what requirements we put on foreign students instead of requiring them to go home, requiring them to become U.S. citizens.

I am just sort of wondering what your thoughts are. Should we approach a strategic plan in this way? Who would be the right group of people, not just in government, to engage in that type of activity?

Dr. VARMUS. You are raising a lot of issues here. With respect to attracting better people into science, an issue about which both Neal Lane and I feel very strongly, our agencies and our agencies in collaboration with other government people, people from universities and other arenas, have been engaged in ways to try to improve and interest young people in science.

The Office of Science and Technology Planning is going to have a workshop on science education in the next few weeks in which some of these issues will be aired, and the National Academy of Sciences has been very interested in trying to change the curriculum in science.

In my own area of biology, there are new standards for the teaching of science in schools, and all these are directed toward broad recruitment of minorities and women into scientific occupations.

Dr. LANE. I wish I had the answer, Ms. Lofgren, to the question about how to get at the strategic issue. I have a view on it that it is going to require a kind of partnership between government, universities, business, and industry that we haven't had before, a qualitatively improved, strengthened interaction in thinking about the future that we have not seen in the past.

I still see divisions where there really ought to be hard work and cooperation with one another if we are going to have a strategy.

NSF, as you know, invests $600 million or more in education, science, mathematics, engineering education, and a substantial part of that in K-12 education. We have been given the responsibility to do that, and it is a role that we very much appreciate having and continue to emphasize.

We believe that that is where we have to start. We have to educate young people from all communities, all backgrounds, to the excitement and the potential value to their own lives of education in science and mathematics.

It is something we feel strongly about, and the way we go about it is to work with institutions, states, cities, universities, K through 12 systems on experiments. When something works or when something doesn't work, spread that information more broadly and try to leverage this relatively small percentage of the overall investment in that area.

Finally, if I could, Mr. Chairman, just add a comment on the foreign student issue. At a time when we are having job problems, which we certainly are right now in many fields of science at the Ph.D. level, it gets even harder to convince members of underrepresented communities to look more favorably on science and engineering, the Ph.D. route in particular, than some of other fields. But it is probably even more important that we find a way to do that.

If our system had not been so strong over the last 20 years, if we had not been able to attract here the students from India and from China and from other parts of the world, think how much knowledge this Nation would have lost, think what the cost to this Nation would have been of not bringing in those students.

It was a very wise move, in my view, to do it. But in the short term, it has created a complex set of reactions because if you don't have a job, the unemployment is 100 percent. And so one can understand the disappointment and unhappiness of our young people right now.

But there is real value to the country and has been and continues to be in having these outstanding young people come, and, yes, we expected that they would go back and that would be good for our relationship with other countries because often they become leaders in the other countries. That is a valuable benefit far broader than science and technology, but there will be a loss to the Nation.

Ms. LOFGREN. I don't know if my time is up, Mr. Chairman.

Mr. SCHIFF. The lady is recognized another two minutes.

Ms. LOFGREN. Thank you.

My comments about the foreign Ph.D. and postdoctoral students in industry is not meant to be critical because I do think industry tends to hire who they need to be successful. That is the nature of the market. And if you talk to CEOs of the most successful companies in Silicon Valley, they basically say they would have to move were they not able to hire the most creative person for whichever job it is.

I just wanted to clarify that my comments were not adverse to that, but I think we have had a very patronizing attitude toward the other countries of the world. I mean, frankly, our immigration system is such that we require people to return even when they don't want to, and I am not sure we need to nurture our economic competitors in that way in today's economic environment.

Mr. SCHIFF. Would the lady yield for one moment on that?

I wonder particularly, Dr. Lane, if you would just clarify and as Ms. Lofgren says, it is not a matter of being judgmental, it is a matter of clarification, what has been our goal in attracting so many foreign graduate students?

Is the object to increase our own eventual pool of practicing professionals here in this country? Or has the object been to help educate professionals in other countries with the objective they will help improve their own countries and create better relations with the United States?

Dr. LANE. Mr. Chairman, I am not sure that there was such a well-defined goal established in the past that then somehow led to this increase in students coming. The facts are that there was substantial growth in research funding in universities. Key to carrying out that research, obtaining the new knowledge and technologies that are good for the Nation, was having the key personnel involved in the process. And in universities, what it is all about is an integration of research and education, undergraduates, yes, but also graduate education in ways that Mr. Bartlett and I exchanged views on earlier.

So I believe that it largely was a fact that the traditional cohort in the United States decided to do other things with their lives than science and engineering at the Ph.D. level, and therefore there was the availability of positions here in our graduate schools for students from other countries, rather than there being a well-defined strategy.

Dr. VARMUS. Let me comment just briefly on the perception in the biomedical field where there still is a very strong interest on the part of American youth to enter the field. We see a substantial number of foreign students in our programs as evidence for the leading role that our programs have in science internationally.

It is a very healthy sign that students from all over the world want to come to the U.S. to obtain training in biomedical research, and we are very grateful for receiving from other countries in the world some of the very finest students and have them here for training because they return. We have had them during the very productive training process, and they strengthen the international aspects of science, which we are very concerned, and if they stay they often become very important components of our scientific establishment.

Mr. SCHIFF. If the lady will continue to yield another moment, what Dr. Lane was referring to, for whatever reason, a certain lack of numbers of students applying to be graduate students in an era when there were slots for those graduate students. To the best of my knowledge, it is extremely difficult for American students to get into medical school now. So, if that is a correct presumption, then what would be—I mean I agree with you we are flattered to have international interest in our medical schools, but if American students can't get in, what would be the justification for bringing in non-American students?

Dr. VARMUS. When I talk about biomedical research, I am talking largely about students who are in Ph.D. programs. Often, in medical schools, not always, but often our medical school classes are still virtually all U.S. citizens.

Mr. SCHIFF. I am sorry, I didn't understand that distinction. Thank you for clarifying that.

Ms. LOFGREN. Mr. Chairman, if I just may briefly, and I would love to have an opportunity, I realize our time is limited here to discuss this further and receive further comments, but, for example, the J2 visa that requires exchange students to return for at least two years to their native country, these tend to be the very brightest young people in a foreign nation whom anybody would want to attract. And yet after we train them and they might want to stay, and many of them do, we require them to leave.

I guess the question I am asking is if we are going to be competitive in a global environment, shouldn't we take a look at every aspect of what we are doing and make sure that it advantages our country rather than an economic competitor?

Mr. SCHIFF. If the lady will yield one more moment, I want to say I completely agree. I am not at this point trying to say what our own national policy should be.

Ms. LOFGREN. Nor am I.

Mr. SCHIFF. I can see justification for saying we need more professionals here and I can see justification for saying that we would

like to see more U.S.-educated professionals, but it would seem to me that we ought to know what we are doing.

Ms. LOFGREN. There ought to be a definition and a strategic plan on what we are trying to accomplish here, and that is really what my original question is. All of us care about it. None of us has the answer, but it seems to me important that we put together a multifaceted, long-range think plan on how we are going to get to where we need to be in the 15 or 20 years from now.

Mr. BARTLETT. If the lady will yield for just a moment, I think there may be another dimension here. It was my privilege this spring to give the commencement address at two of our high schools in a really very rural district. Only two high schools in that whole district, in that whole county. Southern High had 200 students in it. One of them was a minority, only one, an Asian American student. She was the valedictorian.

I then went that afternoon to give the commencement address at Northern High, 150 students there. Only one minority student there. Again, an Asian girl. She was the valedictorian.

I think there is another dimension here, and that is that these students, these families, I think it is more than the students, these families understand the importance of education and have a focus in that direction.

So I think that is another reason that we have such a large percentage of these very talented young people in these programs.

Ms. LOFGREN. Thank you, Mr. Chairman.

Mr. SCHIFF. I want to thank the witnesses again.

I have one request of the witnesses, if they would. We now have the report from the National Academy of Sciences, which has been the subject of this hearing. We have you as representatives of the agencies that in one way or another are largely addressed in the issues that are presented in that report. I would be grateful if, say in the next 90 days, each of you on behalf of your agencies or someone you designate from your agencies would send a letter to me and to Mr. Geren saying that this is what we are going to implement of the report and this is how we are going to do it.

I am not presuming to dictate what portion of the report, if any, you want to implement. I think you are in the process of reviewing it now. But I would like to be apprised of what exact use your agencies make of this report. If you need more time than that suggested 90 days, I would be pleased to extend it.

Mr. BROWN. Mr. Chairman?

Mr. SCHIFF. Mr. Brown?

Mr. BROWN. May I be recognized for just one final brief comment?

Mr. SCHIFF. Yes, sir.

Mr. BROWN. I concur with what the Chairman has suggested, and I want to commend him again for opening the subject up to the light. I am still somewhat disturbed, amongst all the positive things that we have learned. We still have a paucity of information about the exact condition of this great system of scientific education, which involves training a lot of Ph.D.s and putting them out into the world as postdocs. We don't know what is happening precisely in terms of the lengthening period of postdocs, the remunera-

tion of postdocs. We may hear from the next panel a little bit more about that.

But I have a sneaking suspicion that the science establishment benefits from this and may close their eyes to some of these conditions. And both of you gentlemen are true statesmen of science. I think you can overcome any bias that the institutions might have because you like a big supply of cheap labor to do research in universities and reach a better understanding of what the equities are and what the big system requires.

We need to look at a larger system than just this university research system which is the center of this problem and see what we can come to, looking at the larger system including the global system.

There are many good things about what we do. Many of these foreign postdocs go back and become esteemed professors. The new university in Hong Kong is using a lot of these people, for example, who were trained in the United States.

But I don't want us to overlook a good, factual review of just what is happening here, and see if we can't get to the heart of the problem a little bit better than we have been.

Dr. VARMUS. Mr. Chairman, in my own field of biomedical research, the postdoctoral training program is a very important component of our training. The report that we are considering today, of course, is addressed only to predoctoral graduate education.

But I agree entirely with Mr. Brown's remarks that a thorough review of our training programs needs to include perspective on the postdoctoral component as well.

Dr. LANE. I also agree, and, Mr. Chairman, we will respond to your request and continue to provide information to the Committee on the points that you have made and Mr. Brown has just made.

Mr. GEREN. Mr. Chairman?

Mr. SCHIFF. Mr. Geren?

Mr. GEREN. In the letter that the Chairman has asked you all to prepare, I would ask that you also include a comment on the recommendation on the NAS report regarding tracking career paths of Ph.D.s and the recommendation that perhaps we track them for ten years, Ph.D.s generally.

But I would be more interested in trying to judge what we are doing and track those that you all had made an investment in of some sort and see where they are going, if there would be some way to break out those two categories of Ph.D.s. in general and Ph.D.s in which the Federal Government has made some sort of direct investment. That would be helpful to the Committee. I want again to thank both of you for your testimony. Dr. Lane, this weather here probably makes you wish you were back in the brisk, cool Houston.

[Laughter.]

Dr. LANE. Mr. Geren, as nice as the people are here, I am still feeling pretty good about the Virginia climate.

Mr. GEREN. Thank you again.

Mr. SCHIFF. Thank you, gentlemen, very much.

I would like now to thank you and call up our next panel.

Our next panel is Dr. Joseph Miller, Senior Vice President of Central Research and Development at the Dupont Company in Wil-

mington, Delaware; Dr. Ned Heindel, Department of Chemistry at Lehigh University, and past President of the American Chemical Society; Dr. George Walker, Chair of the Council of Graduate Schools, Vice President for Research and Dean of the Graduate School at Indiana University; and Dr. Mark Wrighton, Chancellor of Washington University and a former provost of the Massachusetts Institute of Technology; and Dr. Kevin Aylesworth, founder of the Young Scientists Network, Gaithersburg, Maryland.

Gentlemen, before you begin, I have to say that our previous witnesses are accustomed to this, and if you have testified before Congress before, you would be also, to the comings and goings of Members of Congress.

I want to assure you that no disrespect or disinterest is associated with that. But we have a number of things happening at the same moment. The reason a record is being made of this hearing is so that in due course it will be transcribed and made available to all Members of Congress.

I say that because I am now at the point where I have to excuse myself to take care of certain other matters that are pending at this time, and I am going to ask the full Committee Vice Chairman, Mr. Ehlers, to take over the chair for me.

I want to say that while we are doing that, without objection, all of your written statements will be made part of the record and that you are free to begin and to summarize as you see fit.

I will just begin on my left with Dr. Aylesworth, if you would.

STATEMENT OF DR. KEVIN AYLESWORTH, FOUNDER, YOUNG SCIENTISTS NETWORK, GAITHERSBURG, MARYLAND

Dr. AYLESWORTH. Thank you very much. I just noticed that all the people testifying today are male, and if you have any questions of some female scientists, some of my colleagues in the audience would be more than happy to answer your questions.

I thank the Subcommittee for allowing me to testify on this critical issue. I have served as the elected representative of such national organizations as the American Physical Society, and I have experience in seeking out and presenting the views of my constituents. This testimony is a distillation of ideas garnered over the last five years in conversations with scientists and engineers who are not tenured or who are pursuing alternative careers. I have attempted to accommodate as many views as possible, and I am particularly indebted to life scientists Dr. Eliene Augenbraun and Dr. Mary Jane Finley Austin for their extensive input and intensive review of this testimony.

The views expressed here are not the official views of any organizations with which I am affiliated.

It is apparent there have been significant policy shifts with regard to federally funded research without requisite discussion about where we want to go.

During the post-World War II era, the products of universities were understood to be basic research and a domestic supply of scientists and engineers. About 25 years ago, U.S. citizens, responding rationally to market signals, fled graduate schools and were replaced by foreign students without much discussion.

One aspect of the silent policy shift is that graduate students now tend to be viewed as an inexpensive, disposable labor pool for the university-based research enterprise, rather than one of its principal products. It is time for all participants in the system, including graduate students, postdocs, other temporary workers, and scientists and engineers in nontraditional roles to discuss what our policy should be.

Moreover, it is not enough to merely listen to these currently disenfranchised groups. They must become part of the power structure in science. Once the new policies are determined, they must be stated clearly.

In order for these policy discussions to progress, we need to know the state of the system. This is hampered by severe lack of timely and relevant data. One must wonder why funding agencies which are responsible for keeping track of these issues have ignored these gaps.

Sadly, the National Science Foundation has a history of misrepresenting supply/demand data. See the record of an April 8, 1992, hearing which details the dubious origins of the now-discredited scientist shortfall stories circulated by the NSF in the mid-1980's to the 1990's.

Some data problems persisted even after this hearing. The 1993 edition of Science and Engineering Indicators was marred by serious errors, distortions of fact, and omissions. To Dr. Lane's credit, he inherited much of the data problem from his predecessors, and he has talked openly and honestly about the job situation.

However, it remains to be seen if this concern is being translated into proper data taking, analysis, interpretation, and policy coordination.

Maintaining a diversely trained domestic supply of scientists and engineers that reflects the gender and ethnic composition of the United States is still in the best interest of the country. The pool of graduate students should be allowed to shrink or grow in response to changes in the demand in the end-user market. Government-mandated numerical caps on the number of graduate students should not be imposed.

The system can be made more responsive to the external market signals by shortening the time to degree or, better still, the time to first employment in a potentially permanent position.

Although universities should not strictly control the time to degree, there should be limits on how long students and postdocs can receive Federal funding. This time limit should be based on a training clock that can be stopped for reasons like parental leave or illness.

In addition, graduate students are too often tied to problems chosen by their mentors. In order to increase their independence, funding of graduate students could be shifted from research grants to peer review institution-based educational grants and fellowships directly to the students.

Ph.D. departments should be required to track students for at least ten years after they receive their degrees. However, care must be taken into using ultimate career outcomes to determine funding levels and allocations. Career success should not be defined as teaching and research only as it is today.

It is in the best interest of the country to have science-trained individuals employed in all sectors of our economy. One way this can be accomplished in the long term is by broadening the education of scientists and engineers, but for the growing postdoc field, alternative careers is little more than a buzzword that soothes the establishment. There are very few data on what other career opportunities exist for scientists and engineers and virtually no data on how they move from the traditional job market to other careers, and there is no mechanism to ease the transition.

Foreign students make great contributions to our graduate educational system, and they should continue to have access to our schools. However, the issue of maintaining a balance in the domestic market for scientists and engineers should take precedence.

There are many possible mechanisms for balancing these interests. One is to limit the number of foreign students to some percent of the total. Another mechanism is to insist that other countries be as open to our students and workers as we are to theirs.

There is an urgent need to reassess the national policy on graduate education in science and engineering. The challenge is to fashion new policies for exploring the endless frontier that are appropriate for an era of limited Federal resources. This will require the imaginative input from and the cooperation of all segments of the enterprise. The COSEPUP report is a good first step in that process.

[The prepared statement of Dr. Aylesworth follows:]

Testimony of Dr. Kevin D. Aylesworth
Before the Basic Science Subcommittee of the Science Committee
of the House of Representatives

GRADUATE LEVEL SCIENCE AND ENGINEERING EDUCATION: An Assessment of the Present; a Look into the Future.

July 13, 1995

I thank the Committee for allowing me to present my testimony on this critical issue. I have served as elected representative in various organizations and have experience in seeking out and presenting the views of my constituents. This document is a distillation of ideas garnered over the last five years from conversations with scientists and engineers who are not tenured or who are pursuing 'alternative' careers. I have attempted to accommodate as many views as possible, and am particularly indebted to Dr. Eliene Augenbraun and Dr. Finley Austin for their extensive input and intensive review of this testimony. The views expressed here are not the official views of any organization with which I am affiliated.

HISTORICAL CONTEXT

For better or worse, the world has changed dramatically since 1945 and the social contract embodied in Vannevar Bush's "Science: The Endless Frontier" has expired. If one looks at the history of federal support for science and engineering, it quickly becomes apparent that there have been significant policy shifts with regard to federally funded research without the requisite discussion about where we want to go.

During the post-World War II era, the products of universities were understood to be basic research, and *a domestic supply of scientists and engineers*. These scientists and engineers were supposed to be trained to do basic research and *produce new products and services* from that research. Moreover, the amount of research that could be done was limited only by the number of researchers. At the time it made sense to construct a system based on the exponential growth of the numbers scientists and engineers. Of course, this system required a commensurate growth in funding.

About twenty-five years ago the money that the U.S. government was willing and able to spend on research started to level off, and the system became resource limited. But the mechanism producing exponential growth in the number of researchers remained. When U.S. citizens responded rationally to the market signals and fled graduate schools, they were replaced by foreign students in an attempt to keep the exponential growth going. One aspect of this silent policy shift is that graduate students now tend to be viewed as an inexpensive and disposable labor pool for the university-based research enterprise, rather than one of its principal products. Maintaining the domestic supply of scientists and engineers, and transforming the fruits of basic research to meet national needs generate much lip service -- but not much serious consideration.

It is time for *all* participants in the system, including graduate students, postdocs, other temporary workers, and scientists and engineers in non-traditional roles to discuss what our policies should be in light of changes in the domestic and international economies and constraints on federal spending. Once these policies are determined they must be stated clearly. For instance, if it is decided that the policy is to continue to link the number of graduate students to the needs of the university research establishment for inexpensive labor, then the graduate students need to be informed from the beginning that their presence in graduate school has absolutely nothing to do with their chances of obtaining a job relevant to their training.

THE DATA PROBLEM

In order for these policy discussions to progress we need to know the state of the system now. This is hampered by a severe lack of timely and relevant data, as is recognized in the COSEPUP report. Many of these gaps are at least a decade old. For instance, almost nothing is known of the ultimate fate of postdocs, or whether scientists who take nontraditional jobs are hired in spite of, or because of, their education. One must wonder why the funding agencies, which are responsible for keeping track of the these issues, have ignored these gaps. Perhaps it is the apparent conflict of interest in their duties.

The National Science Foundation (NSF) has a history of misrepresenting supply-demand data: see the record of an April 8, 1992 hearing before the Subcommittee on Investigations and Oversight of the House Committee on Science, Space, and Technology, "Projecting Science and Engineering Personnel Requirements for the 1990s: How Good Are the Numbers?" This report details the dubious origins of the now-discredited 'scientist shortfall' stories circulated by the NSF from the mid 1980's to 1990. The apparent purpose of NSF's stories was to extract more money from Congress. Some data problems persisted even after this hearing. In the 1993 edition of *Science and Engineering Indicators* (released in March, 1994), the discussion of the current employment situation was marred by serious errors, distortion of fact, and omissions (see attachments 1 and 2). To Dr. Lane's credit, he inherited much of the data problem from his predecessors, and he has talked openly and honestly about the job situation. In addition, NSF representatives appear at meetings devoted to the issue. However, it remains to be seen if this concern is being translated into proper data taking, analysis and interpretation. The next edition of *Indicators* will tell.

POLICY RECOMMENDATIONS

Maintaining a diversely trained domestic supply of scientists and engineers that reflects the gender and ethnic composition of the United States is still in the best interest of the country. Government-mandated numerical caps on the number of graduate students should not be imposed. The pool of graduate students should be allowed to *shrink* or grow in response to changes in demand in the end-user market. The system can be made more responsive to external market signals by shortening the time to degree, or better still, the time to first employment in a potentially permanent position. Although universities should not strictly control the time to degree, there should be limits on how long (based on a 'training clock' that could be stopped for reasons like parental leave or illness) students and postdocs can receive federal funding. In addition, graduate students are often too tied to problems chosen by their mentors. In order to increase their independence, funding for graduate students could be shifted from research grants to peer-reviewed institution-based educational grants and fellowships directly to the students.

As the COSEPUP report suggests, PhD-granting departments should be required to track students for at least ten years after they receive their degrees. These data should be entered into a

national career tracking database for use by students, administrators and funding agencies. However, care must be taken in using ultimate career outcomes to determine funding levels and allocation -- 'career success' should not be defined as 'teaching and research' only.

Currently, students and their potential employers are led to believe this definition of success, and this must change. It is in the best interest of the country to have science-trained individuals employed in all sectors of our economy. One way this can be accomplished, in the long-term, is by broadening the education of scientists and engineers. But for today's PhDs, 'alternative careers' is little more than a buzz-word that soothes the establishment. There are very few data on what alternative career opportunities exist for scientists and engineers, and virtually no data on how they move from the traditional job market to other careers. These data are needed to help guide graduates and employers in the future. To be taken seriously in the broader job market the PhDs often need additional training or experience in the new field. Perhaps retraining grant programs could be set up to assist the current generation make the transition.

Foreign students make great contributions to our graduate educational system, and they should continue to have access to our schools. However, the issue of maintaining a balance in the domestic market for scientists and engineers should take precedence. There are many possible mechanisms for balancing these interests. One is to limit the ratio of foreign students to some percentage (less than 50%) of the domestic students. Another mechanism is to open foreign education and job markets to U.S. scientists and engineers -- at present, U.S. scientists and engineers face restricted access to foreign markets. We could insist on some form of reciprocity.

CONCLUSION

There is an urgent need to reassess the national policy on graduate education in science and engineering -- especially in light of the funding reductions that will necessarily follow from eliminating the federal budget deficit. The challenge is to fashion new policies for exploring the 'endless frontier' that are appropriate for an era of limited federal resources. This will require imaginative input from, and the cooperation of, all segments of the enterprise. The COSEPUP report is a good first step in that process.

BIOGRAPHICAL SUMMARY

Dr. Kevin D. Aylesworth:

Kevin D Aylesworth received his PhD in experimental condensed matter physics from the University of Nebraska in 1989. After graduation he served as a National Research Council Postdoctoral Associate at the Naval Research Laboratory in Washington, DC. His research papers on magnetic films appeared in *Physical Review Letters*, *Physical Review B*, the *Journal of Applied Physics* and the *Journal of Magnetism and Magnetic Materials*. During his postdoc he founded the Young Scientists' Network to alert policy makers to the deteriorating job market in science. His articles on scientific employment appeared in *Newsweek Focus*, *APS News*, *Physics Today*, and *Connection*. He is coauthor (with Sheila Tobias and Daryl Chubin) of a book, "Rethinking Science as a Career: Perceptions and Realities in the Physical Sciences," to be published in July 1995 by the Research Corporation. In 1993 Aylesworth was elected for a four-year term as a general councillor of the American Physical Society. After his postdoc he became a self-employed technical consultant. His first contract was to provide expert advice on the scientific method to lead counsel for Daubert in the 1992 Supreme Court case *Daubert v. Merrill Dow Pharmaceuticals*. He has been working as computer and networking consultant since 1993, and will be serving as the 1995-95 American Physical Society Congressional Fellow in September, 1995.

Dr. Kevin D. Aylesworth
2456 Massachusetts Ave. #404
Cambridge, MA 02140
kda@pinet.aip.org
(617) 491-9872

Dr. Neal Lane
Director
National Science Foundation

Dear Dr. Lane, 3-28-94

I would like to express my appreciation for your concern about the employment problems of young scientists. It is obvious from what I've read that your concern is genuine. I wish I could be certain that everyone at your agency and on the National Science Board shares your understanding of our plight. Alas, my reading of Chapter 3 in *Science and Engineering Indicators* (regarding the Science and Engineering Workforce) leads me to believe that some at the NSF and NSB want to continue to play political games at the expense of young scientists. This letter is to point out exactly what I find offensive, and to request your assistance in setting the record straight.

Problems with Chapter 3 start on page 68. The section labeled "S&E Market Conditions" admits that there is a controversy surrounding the supply and demand of scientists and engineers, but completely omits any mention of the NSF's role in concocting the shortage mythology (The Myth). Moreover, this section strongly implies that The Myth is the result of a study by Richard Atkinson -- nowhere is it mentioned that he based his study of PhD supply on an NSF study of undergraduate supply. I realize that it is an embarrassing episode in the Foundation's history that predates your appointment. However, the continued unwillingness of NSF and NSB officials to admit any responsibility for The Myth only breeds more resentment and anger from those of us who are directly affected by it. I don't see how the consequences of admitting responsibility for The Myth can be worse than the consequences of perpetuating this embitterment.

Another major flaw in this report is the lack of attention given to postdocs and other temporarily employed PhD's. The only paragraph that does mention them -- the first full paragraph on page 77 -- is close to being an outright lie. In particular, the assertion that "[t]he most recent NSF data (which cover years through 1991), however, do not show a sizable increase in the number of postdoctorate appointments" is dangerously vague and misleading. First of all, there is no indication of whether the change in the number of postdocs was measured over minutes, days, weeks, months, years, decades or centuries. In addition, it is not clear if the number of postdocs increased in some fields while decreasing in others. Second, according to an article by Kate Kirby and Roman Czujko in the December 1993 issue of *Physics Today,* the number of physicists holding postdocs in doctorate-granting departments rose from 1287 in 1980

to 1721 in 1991. *Their source was NSF report 93-302.* At least for physics, the statement in *Indicators* is false unless one makes the unlikely assumption that the number of physics postdocs in industry and government labs declined over the same decade. Third, the number of postdocs does not even begin to tell the whole story of temporarily employed scientists -- there are large numbers of soft-money researchers and temporary positions not listed as postdocs. In addition, postdocs that are intended to last one or two years are often extended. Postdocs and other temporary employees must be fully included in any believable study of the market for scientists. Relegating them to one short and misleading paragraph is not acceptable.

My final major complaint concerns the large table at the top of page 77 labeled, "Average annual salary offers to doctoral degree candidates in selected fields: 1988-93." The magnitudes of the salary offers for physicists seem way too high and are apparently based of fewer than 20 job offers each. From data I've seen elsewhere, the numbers quoted in the table cannot possibly include postdoctoral salaries. Since postdocs are considered to be fully employed throughout this section, it is natural to assume their salaries will be included in any table purporting to show "average annual salary offers to doctoral degree candidates." I called Patrick Mulvey at the Employment Statistics Division of the American Institute of Physics. He told me that, according to their statistics, the average salary was $34,700 and the median salary was $32,000 for all PhD's who graduated in 1992 and found full-time jobs in the United States -- quite different from the $40,940 figure in the table. I see no legitimate reason for using a table that is based on such a small sample size and that omits postdoctoral (or any other) salaries without explanation. This is especially puzzling because the professional societies can provide nearly complete statistics.

The scientific employment problem has been apparent to my generation for at least four years. Why do some of your colleagues at the NSF and NSB refuse to take the situation seriously? I will be in Washington, D.C. from April 19 - 24, and would appreciate a meeting with you and/or those directly responsible for the content of *Indicators* to clear up any misunderstandings.

Yours truly,

Kevin Aylesworth

CC: Daryl Chubin
Kenneth M. Brown
James J. Duderstadt

Attachment 1

NATIONAL SCIENCE FOUNDATION
4201 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22230

nsf

OFFICE OF THE
ASSISTANT DIRECTOR
FOR SOCIAL, BEHAVIORAL
AND ECONOMIC SCIENCES

April 28, 1994

Dr. Kevin D. Aylesworth
2456 Massachusetts Ave. #404
Cambridge, MA 02140

Dear Dr. Aylesworth:

Thank you for your letter about the employment problems of young scientists. The Director asked me to reply, as *Science and Engineering Indicators* is produced in my directorate. The Director and I share your concern about the difficult employment situation and would certainly agree that we need good data and good analysis of the problem so that policy makers can shape appropriate responses.

I would point out, however, that your letter focuses on a chapter in *Science and Engineering Indicators* which many times acknowledges the employment problems of young scientists. Indeed, this topic is featured in the overview, has a whole section devoted to it, and is mentioned throughout the chapter. Moreover, the author of the chapter went beyond NSF data to professional associations for more timely information on the employment situation. In fact, your own Young Scientists Network is mentioned to illustrate the extent of concern about employment problems. There is no question that the members of the National Science Board and the authors of *Science and Engineering Indicators* are sensitive to employment problems of new PhD's and consider them to be of the greatest importance.

Nevertheless, I would agree with you that there are additional data, not included in the chapter, that would have further documented the situation For example, the brief reference to NSF's data on postdoctorate employment should have included a time frame (1988 through 1991) and should have identified the specific fields covered (physics, chemistry, and mathematics). You are correct that NSF data show postdoctorate employment in physics (and some other fields too) steadily increasing through the 1980's and into the 1990's. It is difficult, however, to determine how much of this increase reflects current problems in the job market, and how much is part of a long term trend. In the future, we plan to do a more thorough analysis of the postdoctorate data, including examining the data by individual field.

Attachment 2

Your criticism of the College Placement Council's data on the beginning salary offers is valid But I think you should know that every effort was made to use similar data from professional associations. Unfortunately, there were major comparability problems that meant that data from the associations could not be combined into one table. Please note that the point of the table you cite was to document the slowdown in entry-level salary growth, thereby illustrating the growing supply of new PhD's in the job market.

I understand that you discussed your concerns with Dr. Brown. Please feel free to contact him again should you wish to discuss these matters further.

Sincerely,

Cora B. Marrett

Cora B. Marrett
Assistant Director

cc: Daryl Chubin
Kenneth M. Brown
James J. Duderstadt

Attachment 2

Mr. EHLERS. [presiding] Thank you, Dr. Aylesworth. I appreciate the speed with which you went through that.

Dr. Wrighton?

STATEMENT OF DR. MARK WRIGHTON, CHANCELLOR, WASHINGTON UNIVERSITY [FORMER PROVOST, MASSACHUSETTS INSTITUTE OF TECHNOLOGY], ST. LOUIS, MISSOURI

Dr. WRIGHTON. Thank you very much. I am pleased to be here as well, and I compliment the members on their interest in addressing this issue. The discussion that was held this morning was extraordinary. I was really privileged to have been here to participate as a member of the audience and to learn from you as you debated among yourselves some of the issues before us.

It is also appropriate that this hearing be conducted before the Subcommittee on Basic Research because advanced education in America owes its evolution as one that is now preeminent to the close coupling between advanced education and research.

One of the key issues we have been addressing here is the possible oversupply of Ph.D.s. It is my view that the United States cannot have too many highly educated people. Therefore, the discussion really must concern the nature and character of the Ph.D. experience.

I have had the opportunity to participate in some of the discussion that surrounded Ph.D. education, and I find myself in concert with the views that have been expressed by Dr. John Armstrong, formerly of IBM, who has expressed the view that Ph.D. programs often are too narrow, too long, and too campus-centered to meet the needs of industry. There is certainly a need for the Ph.D. experience to be one focused on addressing the research problem of interest and significance and to demonstrate progress in solving them.

However, there is a need for Ph.D. recipients to understand the industrial world into which they will likely be recruited even if the Ph.D. recipient is to pursue an academic career. It should be understood that the students that these faculty members will prepare are very likely to pursue careers in industry and it is appropriate that we the academicians had better understand the needs of the industries that we serve.

Understanding the world of industry can be accomplished by more fully developing the partnership between universities and industry and by expanding the opportunities for collaborative research, including time at industry sites with graduate students and time at the universities for members of the industrial team.

At the present time, there is an understood need that there are not incentives on either the industry or university side to encourage the expansion and strengthening of the industrial partnership with universities.

There are other entities with which university partnerships might yield a broadened Ph.D. experience, including interactions with government laboratories and research institutions. In addition to providing opportunities for interaction with industrial and other collaborators, the industrial experience should include broadening subjects including ones in the student's so-called specialties. I have observed as a chemist that too many students do not have the breadth and depth of chemistry needed for the changing careers

they will face, let alone the skills needed in allied sciences and engineering and in communications.

Further, much of the developed and developing world is aggressively pursuing advanced research in their own areas, and Americans need to know much more about what is being done in other countries and more about other cultures. Thus, the graduate experiences need to be broadened.

While broadening the graduate experience in science and engineering to include additional learning experiences beyond the research problem is important, it needs to be understood that the length of the Ph.D. experience is currently too long. It is not atypical for a student to be involved in the Ph.D. program for five or six years, as you have already heard, and sometimes in other areas, depending on the discipline, the degree takes significantly longer.

The long time to degree and the concomitant costs erode the return on graduate investment in education. As you have already heard, there is no single factor that can be regarded as the dominant one contributing to the long Ph.D. experiences. But one contributor, in my view, is the intense interest in research results and the reward structure associated with it for the faculty mentors.

Sustaining world leadership in science and technology will require more than just being able to solve challenging intellectually stimulating research problems at the cutting edge of knowledge, but it should be understood that the Ph.D. is a research degree and the research experience should remain the heart of the experience.

In suggesting specific changes to the graduate education and research enterprise, it should be strongly emphasized that the adjustments needed are ones related largely to balance. Fundamentally, the system is healthy, world-class, and has served the country well.

There are some changes in emphasis that are needed to better meet today's and tomorrow's needs, and I believe that one way to meet some of the needed changes would be to adjust the balance of support to graduate students in the form of research assistants to include a healthier balance of fellowship and training grant support. As you have heard, there would be many objectives that would be met by the change in balance, including ones related to the educational programs that will be developed by the academic units advancing the training grant programs.

I also believe that the support extended through this mechanism would encourage individual faculty members to take more seriously their role as educational mentors as well as research mentors.

In closing, I want to emphasize again that science and technology leadership is of course vital to the United States, that the graduate education and research enterprise is currently the envy of the world and some changes in balance in the enterprise will contribute to enhancing the U.S. leadership position in advanced education and research.

Thank you very much.

[The prepared statement of Dr. Wrighton follows:]

SUBCOMMITTEE ON BASIC RESEARCH

COMMITTEE ON SCIENCE

U. S. HOUSE OF REPRESENTATIVES

HEARING

"GRADUATE LEVEL SCIENCE AND ENGINEERING EDUCATION"

July 13, 1995

Testimony by

Dr. Mark S. Wrighton
Chancellor
Washington University in St. Louis

Mr. Chairman and Committee Members, I am Mark S. Wrighton, Chancellor and Professor of Chemistry at Washington University in St. Louis. I am formerly Provost and Ciba-Geigy Professor of Chemistry at MIT where I mentored more than 70 Ph.D. recipients in chemistry. It is a pleasure to be able to speak briefly regarding graduate education for scientists and engineers.

It is appropriate that this hearing on advanced "education" be held before the Subcommittee on Basic Research, because the synergy between advanced education and research has been a key to the evolution of America's preeminence in science and engineering education and research at research-intensive universities. The U.S. is the world leader in graduate education and research, and yet there are definitely opportunities to improve, and indeed, change is needed, in order to sustain a world leadership position and to serve better the interests of U.S. society. What are those interests? In my view, there are five reasons to sustain U.S. leadership in science and engineering education and research: (1) to sustain and proliferate peace, (2) to enhance human health, (3) to ensure economic prosperity, (4) to preserve the environment and to encourage sustainable development, and (5) to enhance the quality of life. America's investment in science and engineering education and research is just that, an investment, and one that has a proven track record. However, this era of change suggests that there is a need to review the investment and to make appropriate changes.

92-585 95 – 4

One of the prevailing concerns relates to the possible "oversupply" of Ph.D.'s. It is my view that the U.S. cannot have too many highly educated citizens. Science and technology leadership is vital to the future of the nation, and highly educated people in large numbers will be needed to sustain U.S. industry. It is worth noting that the research-intensive universities through strong graduate programs in science and engineering have contributed greatly to the development of the biotechnology industry and to the computer industry. Clearly, universities are not responsible for all innovative discoveries, but all innovative discoveries are made by people---people educated in universities. The paramount concern, therefore, is not how many Ph.D.'s are being produced, but the quality and character of the graduate education experience they receive.

I share the view that has been articulated by Dr. John Armstrong formerly Vice President at IBM that the Ph.D. experience is now too narrow, too long, and too campus-centered to meet the needs of industry. There is certainly a need for the Ph.D. experience to be one focused on addressing a research problem of interest and significance and to demonstrate progress in solving it. However, there is a need for Ph.D. recipients to better understand the industrial world into which they will likely be recruited. Even if the Ph.D. recipient is to pursue an academic career it should be understood that the students they prepare are likely to pursue careers in industry, and it is appropriate that we the academicians better understand the needs of the industries we serve. Understanding the world of industry can be accomplished by more fully developing the partnership between universities and industry. Expanding the opportunities for collaborative research, including time at industry sites for the graduate students and time at the universities for the industrial collaborators. At the present time there is an understood need but there are not incentives on either the industry or university side to encourage the expansion and strengthening of the industrial partnership. There are other entities with which university partnership may yield a broadened Ph.D. experience, including interactions with government laboratories and research institutes.

In addition to providing opportunities for interaction with industrial and other collaborators, the graduate experience should include broadening subjects, including ones in the student's so called specialty. I have observed that too many students do not have the breadth and depth in chemistry needed for a changing career, let alone the skills needed in allied sciences and engineering and in communications. Further, much of the developed and developing world is aggressively pursuing advanced

research, and Americans need to know more about what is being done in other countries and more about other cultures. Thus, the graduate experience needs to be broadened.

While broadening the graduate experience in science and engineering to include additional learning experiences beyond the research problem is important, it needs to be understood that the length of the Ph.D. experience is currently too long. It is very typical for the Ph.D. student to spend five or six years beyond a bachelors degree to earn the doctorate. In some fields the time to degree is significantly longer. The long time to degree and the concomitant costs erode the return on investment in graduate education. No single factor can be regarded as the dominant one in contributing to long Ph.D. experiences, but a contributor in some fields is undoubtedly the highly results-oriented reward structure to faculty mentors who support graduate students on their research grants or contracts.

Sustaining world leadership in science and technology will require more than being able to solve challenging, intellectually stimulating research problems at the cutting edge of knowledge, but it should be understood that the Ph.D. is a research degree and the research experience should remain the heart of the experience. In suggesting specific changes to the graduate education and research enterprise it should be strongly emphasized that the adjustments needed are ones related largely to balance. Fundamentally, the system is healthy, world class, and has served the country well. There are some changes in emphasis that are needed to better meet today's and tomorrow's needs.

One way to bring about some of the needed adjustments in the graduate education enterprise is to change the balance of resources devoted to graduate education from an emphasis on graduate research assistants on grants and contracts to more support in the form of fellowships and training grants to institutions and departments. Such training grants and fellowships should be funded at levels that reflect the costs of the education, recognizing both that such education is expensive and that it is a meaningful investment. Note that this is not a call for more money; rather, this is a call for a redistribution of resources. Why would such a re-distribution effect the desired changes in graduate education? Fellowships to students would encourage faculty to offer the best educational programs to attract the best students. Today, students are attracted to faculty who have research grants and contracts to support them. Training grants would encourage entire academic units to develop the best educational programs to attract not only the financial support, but

also to attract the best students. Both training grants and fellowships would lessen the burden on the research faculty in terms of effort expended on research proposals and could lessen the administrative burden on proposers and sponsors alike.

In closing, I want to emphasize again that science and technology leadership is vital to the U.S.; that the graduate education and research enterprise is currently the envy of the world; and that some changes in balances in the enterprise will contribute to enhancing the U.S. leadership position in advanced education and research.

Mr. Chairman, I would be pleased to respond to questions.

Mr. BARTLETT. [presiding] Dr. Walker?

STATEMENT OF DR. GEORGE WALKER, CHAIR, COUNCIL OF GRADUATE SCHOOLS, VICE PRESIDENT FOR RESEARCH AND DEAN OF GRADUATE SCHOOL, INDIANA UNIVERSITY, BLOOMINGTON, INDIANA

Dr. WALKER. I would like to thank the Committee to testify today on the COSEPUP report and discuss graduate education of scientists and engineers.

I am testifying today from the perspective, Mr. Chairman, of the board of directors of the Council of Graduate Schools, the CGS. The Council of Graduate Schools has 412 members throughout the United States and Canada. Its membership includes virtually all constituents of the Association of American Universities, the AAU, and the National Association of State Universities and Land Grant Colleges.

I am also speaking from the perspective as vice president of research and dean of the graduate school at Indiana University and as a faculty member, a theoretical physicist, in physics for a number of years. I have also had the privilege of having my research and training of graduate students funded by the NSF for the last quarter of a century.

I should say, reflecting on this morning's discussion, that I had to become a physicist. Having once had the opportunity to experience the exhilaration of discovery, I had no choice. But now, as I think back on the quarter of a century of that privilege, I would also say that one of the great satisfactions has been the mentoring and training of graduate students.

We believe the COSEPUP report is correct. The U.S. graduate education in science and engineering is distinguished by excellence, but would be improved by maintaining the research training excellence and at the same time allowing for more flexibility in program design and allowing for options that would widen the work and learning environments for students, thus facilitating more versatility in their careers.

The academic community is already responding to the issues raised in the COSEPUP report. I just came from a meeting, a CGS meeting with more than 100 schools represented, where it was discussed. The presidents and chancellors of AAU universities have requested their graduate deans to carefully evaluate the COSEPUP report and make recommendations on how universities ought to respond.

I am a member of graduate deans carrying out that request. I am aware that the Council of Research Policy and Graduate Education, NASULGC, is similarly considering the COSEPUP report.

I would like to stress, as does the COSEPUP report, the importance and lack of, in many cases, availability of data regarding the careers of U.S. Ph.D. graduates, particularly those outside the academic environment. The data-gathering capabilities of the Federal funding agencies, such as the National Science Foundation and the NIH, should be enhanced, and I believe that major research efforts to learn about multiple or flexible career paths in science and engineering are deserving of Federal support.

Rapid disclosure and public discussion of career path opportunities are needed so that developing scholars can make informed choices.

Now I would like to make some brief comments on the questions that were addressed in the written testimony on the issue of limiting enrollments in Ph.D. programs. Of course, there are natural limitations that are already taking place by enrollment decisions made by students, departments, and universities throughout the country. These decisions are based on merit, the job market, and the financial resources for support, among other things.

Market forces are, I believe, already at work in some disciplines. CGS data shows the graduate enrollment leveling off following a decade of increase. A recent American Institute of Physics study indicates that Ph.D.-granting departments decreased their admissions by 20 percent from 1992 to 1995.

I am aware and troubled by the stories of expectations not being met, especially as with regard to employment in the economic sector or underemployment. That does not mean to directly imply an overproduction of Ph.D.s but may result from a mismatch of expectations, especially with regard to academic appointment and more particularly in narrowness of training and inadequate information on career choices within the discipline.

Job markets operate best with minimal Federal control. The Federal role should be to support the development of database information and its dissemination and to support excellence of training of Ph.D.s through competitive awards, including more training grants.

On the issue of time to degree, considerable efforts are already underway in individual institutions to lower time to degree. The AAU, AGS, and CGS publications, which predate COSEPUP, illustrate the many approaches to improving and making Ph.D. programs more productive.

At Indiana University, I founded that the simple availability of time to degree and career data on a department-by-department basis in the hands of the appropriate school dean can provide great impetus for a serious look at this issue.

In conclusion, I agree with the COSEPUP report that science and engineering Ph.D. programs will be improved with students and the Nation better served with more flexibility and versatility that would characterize graduate programs. Research excellence need not be compromised by this approach. In fact, my experience indicates that research productivity will improve because of the broader perspectives gained.

An excellent vehicle for this change would be the consideration of more departmental training grants. I say this even in the extremely stressful funding environment in which we work. The Federal agencies are quite capable of adjusting their criteria for research excellence to include excellence in training Ph.D. graduates. As graduate deans, we want our institutions to continue to graduate the problem solvers our Nation needs.

From my own experience as a graduate dean and professor of physics, I am aware that just because someone has been productive in research does not necessarily mean they will be a good mentor, and I also realize that often, as we are mentored so we will mentor

the next generation of faculty, the graduate students of the morning, some of them are the faculty of the afternoon.

In the process of broadening training for graduate students, we need to also understand that they need to be mentored on how to mentor.

I believe we are in the process of crafting changes in our own graduate programs at individual universities that will broaden the horizons and the interests and opportunities for future generations of problem solvers. In that sense, the COSEPUP report has been very helpful to us.

Thank you for your attention this morning, this afternoon. I am prepared to answer questions that the Committee may have at this time or individually.

[The prepared statement of Dr. Walker follows:]

Testimony of George Walker
Vice President for Research and Dean, University Graduate School
Indiana University

Chairman, Board of Directors, Council of Graduate Schools
One Dupont Circle, Suite 430
Washington, DC 20036

on the
National Academy of Sciences'
Committee on Science Engineering and Public Policy Report
"Reshaping the Graduate Education of Scientists and Engineers"

on behalf of
Council of Graduate Schools
National Association of State Universities and Land-Grant Colleges

Subcommittee on Basic Research
Committee on Science
U.S. House of Representatives

July 13, 1995
Rayburn House Office Building, Room 2318
Washington, DC

Thank you Mr. Chairman for the opportunity to testify today on the National Academy of Sciences Committee on Science, Engineering, and Public Policy Report entitled "Reshaping the Graduate Education of Scientist and Engineers". I am testifying today in my capacity as chairman of the Board of Directors of the Council of Graduate Schools (CGS). The Council of Graduate Schools has 412 members throughout the U.S. and Canada with a growing number of private sector and foreign university affiliates. Its membership includes virtually all constituents of the Association of American Universities (AAU) and the National Association of State Universities and Land-Grant Colleges (NASULGC) as well as many smaller, regional institutions that make up the diversity of graduate education in the U.S. I am also speaking from my position as Vice President of Research and Dean of the Graduate School at Indiana University and as a faculty member in physics for a number of years. I have had the privilege of having my research and training of graduate students funded by the NSF for the last quarter of a century.

The COSEPUP report has it right: U.S. graduate education in science and engineering is distinguished by excellence. That does not mean it can not use improvement. The improvements should be cautious and build on the premise of maintaining excellence while providing options such as increased flexibility in program and course design. Options should also be available for students to experience a variety of settings so that they will be exposed to more work and learning environments facilitating more versatility in their lifetime careers. Flexibility and versatility are hallmarks of the American system of graduate education. I believe that is one of the reasons it has proven to be so robust and desirable from an international standpoint.

It could be said that the international reputation of our institutions of higher learning remains unparalleled. As an example, numerous students and senior scholars from abroad flock to our country to gain the unique training that is obtainable at our major research universities. Indeed, the largest and most powerful "developing" countries send their best and brightest to us by the thousands for training. This is especially interesting because this statement could most appropriately have been made about German universities in the period 1900-1910. At that time, the United States was the major developing country whose students flocked to German laboratories for training. This example makes it clear that we cannot afford to rest on our present reputation.

The academic community is already responding to the issues raised in the COSEPUP report. CGS has just completed a meeting, with more than 100 schools represented, where it was discussed. The presidents and chancellors of AAU universities have requested their graduate deans to carefully evaluate the COSEPUP report and make recommendation for how universities ought to respond; I am a member of a group of graduate deans carrying out that request. The Council on Research Policy and Graduate Education (CRPGE) in NASULGC is similarily considering the COSEPUP report.

The COSEPUP recommendations concerning timeliness and availability of databases are noted, and if anything I believe that they should be given greater emphasis. CGS published the executive summary of the COSEPUP report in a June 1995 newsletter and urged campuses to convene discussions with those responsible for graduate education to consider the report in its entirety. Data on underemployment and non-academic employment, particularly the work done by U.S. Ph.D. graduates outside of the academic environment is difficult to come by and needs to be

developed by policy makers as well as individual institutions. This information would allow our institutions and students better sources of information upon which to base their career decisions. Research money for this type of project is very difficult to raise despite support from the National Science Foundation. As Congress considers the NSF budget and other science related agencies, it is important that the data gathering responsibilities are left in place and enhanced where possible. More detailed research, tracking the career paths of scientists and engineers by private foundations, universities, the National Academy of Sciences (NAS) and other sources of expertise should be strengthened and supported by the federal government. Efforts by the NAS to expand their forthcoming study of Ph.D. programs with such information were unsuccessful. The Mellon Foundation has funded a small pilot study at UC Berkeley, to begin this work. Major efforts to learn about multiple, flexible career paths need support from Federal science agencies.[1] Rapid disclosure and discussion among disciplines, departments and research teams are needed so that our young people can have the best information available to them as they plan their career choices.

Let me specifically answer the questions addressed in the subcommittee charter for this hearing.

1. Should enrollment in Ph.D. programs be limited?

Ph.D. program enrollment is already naturally limited at a number of levels. University enrollment decisions begin at the department level, work through various university and state level controls, and include consideration of the employment market. In addition, the merit based criteria that undergird admission to Ph.D.

[1] "Assessment Flaws Seen in Pending Academic Report," in Science. 23 June 1995. v.23:1693-4.

programs in virtually all fields provides limits on a case by case, department by department basis. Statistics on graduate enrollment indicate that market forces are already at work. CGS data show that total graduate enrollment has leveled off following nearly a decade of steady increase. Moreover, first year enrollment in the physical sciences decreased by 3 percent from 1992 to 1993.[2] A recent study by the American Institute of Physics indicates that the number of first year physics graduate students in Ph.D. granting departments decreased by 20 percent from 1992 to 1995 (see AIP chart attached).[3] This suggests that the enrollment market is already recognizing and taking into account the changes suggested in the COSEPUP report.

There appear to be cycles in the employment picture in various disciplines. In addition, recent Ph.D. graduates in certain subdisciplines have expectations that have not been met due to external conditions which distort job market conditions. I also see much discussion of underemployment in specific areas. Yet I am skeptical as to whether these observations directly imply a surplus of Ph.Ds. Over time both markets and Ph.Ds will adjust for jobs available. The COSEPUP report's long-term data on unemployment reveals that Ph.Ds have very low (approx. 2%) unemployment rates. The talk of an oversupply is often focused on academic employment, but a tight job market for academic positions in some disciplines has

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[2] Syverson, Peter and Moira Maguire. "Graduate Enrollment and Degrees: 1986-1993," CGS/GRE Survey of Graduate Enrollment, December 1994.

[3] American Institute of Physics Education and Employment Statistics Division. "Number of First Year Graduate Students Admitted Into Physics Ph.D. Granting Departments, 1980-1995."

been the case for years. As the COSEPUP report notes, in many science and engineering fields there is substantial employment (exceeding 50%) outside of academic institutions. In short, our information age is making good use of highly trained individuals with good research skills. Job markets operate best with minimal federal control. The federal role should be to support the development of data bases to inform choices and to support excellence through competitive awards. Competition works!

(An additional question is whether foreign student enrollment should be limited in some way. CGS testified before the Congress in 1992 with regard to legislation introduced at that time. Our general recommendation was that foreign student enrollment not be limited in the interest of competitiveness and excellence. I will include a copy of that testimony in the written summary of my remarks for a more detailed discussion of that issue.)

2. Should degree granting institutions strictly control the amount of time its students are enrolled to obtain a degree?

The answer to this question is that there are controls already in place. Nearly every degree granting university that I am familiar with has targeted time to degree for full and part time students, with exceptions granted only by petition or in special circumstances. It is true that the average overall time to degree nationally has increased in many disciplines and the COSEPUP report discusses in some detail

a variety of explanations. Ultimately, every individual institution and department, or academic subgroups within institutions are responsible for the graduate experience, graduate education, and the time to degree. Internal controls are the best for addressing this particular situation. Considerable efforts are underway at individual institutions to reduce time to degree. The AAU/AGS publication, "Institutional Policies to Improve Doctoral Education," and the CGS publication, "The Role and Nature of the Doctoral Dissertation," both predate the COSEPUP report and illustrate the many approaches to improve and make more productive Ph.D. programs.[4] At Indiana University we have found that the availability of time to degree data in the hands of departmental and school administration provides a great impetus to address this issue seriously.

In addition to what is discussed in this report, the single largest variable in time to degree is probably the level of support received. This can vary greatly from field to field and from institution to institution but it is critical to have careful monitoring and judicious availability and flexibility of support at the campus or the departmental level. The COSEPUP report presumes that science and engineering graduate programs will be improved if flexibility and versatility characterize them in addition to some highly specialized skills. I strongly agree with these recommendations.

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[4] Association of American Universities/Association of Graduate Schools (AAU/AGS). "Institutional Policies to Improve Doctoral Education," A Policy Statement of the Association of American Universities and the Association of Graduate Schools in the Association of American Universities, November 1990. Council of Graduate Schools (CGS). "The Role and Nature of the Doctoral Dissertation," A Policy Statement of the Council of Graduate Schools, January 1991.

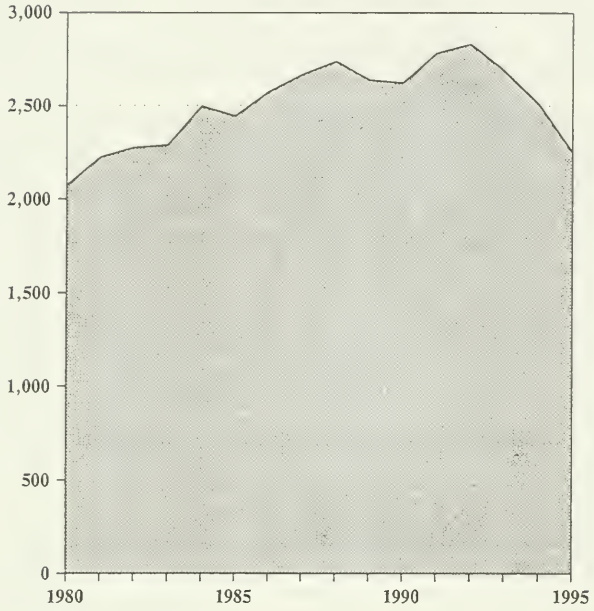
In terms of changing federal government support mechanisms to foster these kinds of programs, the proposal by COSEPUP is consideration of more departmental training grants as opposed to research assistantships. The National Institutes of Health has been doing this for a number of years and NSF has recently revived a program of traineeships. In a declining federal budget, it will be exceedingly difficult to shift support patterns away from competitive research toward competitive traineeships. Many of my colleague Graduate Deans with whom I've discussed this testimony oppose any efforts to reduce funding for research, and thus view any additional traineeships as threats to already stressed resources. I disagree. I believe we should retain research excellence and add excellence in training as an additional goal for which there are award incentives. These adjustments need to be carefully worked out between funding agencies and the discipline/subdiscipline fields. A guiding principal might well be to move these decisions down to the program level and let those closest to graduate students and research careers guide the resource allocations.

The federal agencies are quite capable of adjusting their criteria for research excellence to include excellence in training Ph.D. graduates. As Graduate Deans we want our institutions to continue to train and graduate the problem-solvers our nation needs. I believe we will craft changes in our own graduate programs that broaden the horizons of interest and opportunity for future generations of problem-solvers. The major problem that I anticipate at the Indiana University is simply

keeping research budgets robust enough to allow a significant percentage of the excellent ideas for graduate student research to be funded in an intensely competitive environment.

Thank you for your attention this morning, I am prepared to address questions that members of the committee may have at this time or to respond to questions the committee may have in the future.

Number of First-Year Graduate Students Admited into Physics PhD-Granting Departments, 1980-1995



Source: AIP Education and Employment Statistics Division

Mr. BARTLETT. Thank you.
Dr. Heindel?

STATEMENT OF DR. NED HEINDEL, DEPARTMENT OF CHEMISTRY, LEHIGH UNIVERSITY, [PAST PRESIDENT OF AMERICAN CHEMICAL SOCIETY], BETHLEHEM, PENNSYLVANIA

Dr. HEINDEL. I am Ned Heindel, past president of the American Chemical Society, and I am a professor of chemistry at Lehigh University.

I am somewhat sorry that Congressman Brown has left the room, because we do have specific information collected by the American Chemical Society on the fate of postdoctorates in our field. We tracked down 62 percent of the Ph.D. graduates in chemistry from the 1987-88 year to the present, and we know how many are postdocing then and now. Frankly, we are a little frightened by the data. Now back to my script.

The U.S. graduate system in the sciences and engineering serves this Nation well. In an increasingly competitive workplace, the rapid demands of science and technology and the interdisciplinary nature of much modern research is putting new demands on the scientific and engineering community. Now more than ever our scientists and engineers require highly developed skills for immediate application in their entry positions as well as having the ability to remain continually up to date over decades.

The academy's report proposes appropriate recommendations to meet those growing concerns, and in particular the American Chemical Society heartily endorses the concept of expanding the range of activities that a graduate student undertakes while pursuing an advanced degree.

The current system is effective in producing competent researchers, but it is often accomplished at the expense of some breadth of training. Although a thorough grounding in a specialty is essential for scientists and engineers to function independently, that intense, world-wide research efforts currently underway exploit those specifically- developed masteries honed and sharpened in university study within a very few short years.

As a result, researchers need to be able to move to more or less related areas to find continuing employment. The range of science presented to the student is critical. In determining the ease of this lifelong self-education. A broad knowledge of a given discipline and an acquaintance with related or associated subjects is highly desirable.

New advances are often made at the intersection of these various disciplines. Students need to be better prepared for post-academic careers by exposing them to multidisciplinary efforts early in their career, preferably by their participation or alternatively by being proximate to such activities.

A related research problem may be chosen that combines two or more areas, the student, perhaps working with more than one faculty member at a time or perhaps working with other students, involving different sets of skills and expertise. Learning a teamwork approach to problem solving is essential.

Consideration must also be given to broadening the criteria by which faculty are rewarded in order to include the effectiveness of their graduate and postdoctoral education processes.

As a part of the broadening effort, the American Chemical Society endorses such recent programs as NSF's CAREER and GOALI programs and NIH's biology/chemistry interface training program. Programs such as these provide students with the flexibility and the autonomy to pursue broader research interests.

Another opportunity that should be considered is to better enable grad students to complete all or part of their thesis work in national labs or in an industrial setting. In general, the Society believes that government and industry should support, separately or jointly, positions at universities and in industry that can facilitate such personnel interchanges. Fellowships for senior scholars, internships and co-op programs. These are all excellent mechanisms for such exchanges.

So while change is necessary to increase the versatility of the graduate programs, special care must be taken not to lose the excellence or the purpose for which the advanced degree was created. The ACS concurs with the report that maintaining local initiatives, controlling time to degree, and attracting a diverse group of individuals into the engineering and science disciplines are important.

Looking now at the second overarching set of recommendations that focus on providing better information and guidance on career opportunities, here the ACS supports these heartily. Combining improved information availability with increased autonomy and research experiences will greatly enhance the productivity of the graduate education system.

In particular, market forces will prevail. Those faculties who are successful in training students and in providing opportunities for successful careers for their students will attract the best students. Those who take advantage of the students for their own research agendas without regard to career opportunities for those students will ultimately be unable to attract top-quality students.

Providing career information for members is a priority for the American Chemical Society. The ACS offers a unique collection of hands-on programs of services and of products specially designed to assist the professional and economic futures of chemists.

We are taking advantage of expanding our worldwide web, and the Society is developing an on-line employment database for the chemical sciences. That service will be searchable by both job seekers and job providers. The ACS is exploring the use of the worldwide web and satellite television to offer enhanced information on chemistry-related job opportunities for use by high school students, college students, and graduate career advisors.

These efforts are not enough. Graduate faculty are the most influential mentors and they need to become cognizant that their responsibilities include career development for their students as well as developing the research potential of students.

The ACS is beginning to explore just what those needs are and what opportunities exist to effectively reach faculty with that message. It is clear that many different modes of communication are necessary.

Focusing on the third recommendation, the Society would like to express concern regarding the establishment of a national human resource policy for advanced scientists and engineers'. Establishing such a service would be a formidable challenge and one that would require much thought prior to implementation.

As history has demonstrated, the need for scientists and engineers is cyclical and the market is subject to market forces. These needs are difficult to project.

Additionally, to produce a quality doctoral grant in any discipline takes time. Production is not something you can turn off or turn on like water from a faucet. So while the Society agrees that the goal is desirable, its implementation would be difficult and, if done incorrectly, could be harmful to the Nation.

Finally, considering the length of time it takes to earn an advanced degree, the ACS believes in general that it has become unnecessarily long. Most graduate schools currently do have a policy that degrees must be completed within some time period, five to seven years at the moment, for example.

Unfortunately, abuse of these polices exists, and I think that abuse will become worse as the number of graduate students available for graduate school decreases. This problem deserves attention. For example, the Federal Government should limit its support to only those schools who have a stated and enforced policy that the doctorate must be earned within a certain time period, seven years for students enrolled full-time.

An additional solution might be the establishment of fellowship/traineeship programs that require the university to provide a plan for course work prep. Those awards could be structured so that they would include a time limit of support. Extensions would require that the school show the time to degree for all doctoral students is less than, say, 5.5 years.

That ends my oral comments. Thank you for your attention. I too will be happy to answer any questions you might have.

[The prepared statement of Dr. Heindel follows:]

S T A T E M E N T

of the

American Chemical Society

STATEMENT

of

DR. NED D. HEINDEL

on behalf of the

AMERICAN CHEMICAL SOCIETY

to the

BASIC RESEARCH SUBCOMMITTEE

COMMITTEE ON SCIENCE

U.S. HOUSE OF REPRESENTATIVES

on

RESHAPING THE GRADUATE EDUCATION OF SCIENTISTS AND ENGINEERS

THURSDAY, JULY 13, 1995

American Chemical Society • 1155 Sixteenth St., N.W. • Washington, D.C. 20036 • (202) 872-4466

Mr. Chairman and Members of the Subcommittee:

My Name is Ned Heindel. I am the immediate Past-President of the American Chemical Society and a Professor of Chemistry at Lehigh University. I appear before you today to provide you with the Society's perspectives on graduate education, framed in the context of the National Academy of Science's report, "***Reshaping the Graduate Education of Scientists and Engineers.***"

The U.S. graduate system in the sciences and engineering has served the Nation well. Our past investment has paid off handsomely as evidenced by the United States' technical abilities and its strong, technologically-based economy. However, an increasingly competitive and demanding workplace, the rapid development of science and technology, and the interdisciplinary nature of much modern research is putting new demands on the scientific and engineering community. Industry is moving rapidly in new directions to meet a challenging global marketplace, and universities and government laboratories are adapting to new national initiatives. Now, more than ever, scientists and engineers require highly-developed skills for immediate application in their entry positions as well as the ability to remain continually up-to-date over decades. These new demands have placed strains on the current graduate educational system in the United States. Evidence suggests that our current system of graduate education is not producing the type of student necessary to continue our Nation's excellence into the next century.

In general, the Academy's report presents valid arguments and proposes some appropriate recommendations to meet these growing concerns. In particular, the American Chemical Society heartily endorses the concept of expanding the range of activities a graduate student undertakes while pursuing an advanced degree. The current system is effective in producing competent researchers. However, this is often accomplished at the expense of the breadth of training. The largely specialized graduate training of recent decades worked well in the rather stable environment of that period. Professionals developed expertise in new technical areas over a period of years. Companies and granting agencies took a longer term view, which encouraged the scientist and engineers to develop and apply new expertise. The increased rate of change of world-wide research efforts in the recent past and the likelihood that such a pace will continue for years to come, however, places new demands on the educational process and on its graduates. Therefore, while a thorough grounding in a specialty is important for scientists and engineers to function independently, a broad-based training that fosters moving to another, more-or-less related area by a researcher may be necessary for future employment.

Professional renewal requires that scientists and engineers be able to learn new areas while practicing in existing ones. The range of science presented to the student is critical in determining the ease of this lifelong self-education. A broad knowledge of a given discipline and an acquaintance with related or associated subjects is highly desirable. Outside the university, and increasingly inside as well, new advances are often made at the intersections of various disciplines. Students need to be better prepared for their post-academic careers by exposure to such efforts early in their training.

To that end, graduate students must be exposed to multidisciplinary research programs either by their own participation or by proximity to such activities. A research problem may be chosen which combines two or more areas; the student perhaps working with more than one faculty member. Alternatively, two or more students with differing expertise might collaborate; this latter mode is one often found in industry. Consideration also must be given to broadening the criteria by which faculty are rewarded in order to include the effectiveness of the graduate and postdoctoral education processes.

As a part of this broadening effort, the ACS endorses such programs as NSF's CAREER and GOALI (Grant Opportunities for Academic Liaison with Industry) programs and NIH's biology/chemistry interface training program. Programs such as these provide students with the flexibility and the autonomy to pursue broader research interests. Another opportunity that should be considered further is to better enable graduate students to complete all or part of their thesis work in national laboratories and in industry. In general, the Society believes that government and industry should support, separately and/or jointly, positions at universities and in industry to facilitate personnel interchanges. Fellowships for senior scholars, internships, and co-op programs are excellent mechanisms for such exchanges.

An interesting model that merits some consideration is the recently developed German Fraunhofer Institutes. At these institutes, academic and industrial scientist work together to explore applied research opportunities. Graduate students are therefore trained at the technology transfer interface. The European system has introduced a new series of conferences where graduate students meet with industrial scientists to learn about career opportunities and research needs in the various career paths. Approximately one-half of the conference is spent on career development.

In evaluating the cause for the overspecialization of graduate students, it has been stated that too much control of the graduate student's activities lies with the thesis advisor. At present, most graduate students are supported through research assistanships. While research assistantships tied to academic principal investigators have fostered tremendous gains in science and engineering, the shift away from traineeships and fellowships that has taken place over a twenty-year period may be hindering the opportunities for students to pursue a broad education in the scientific and engineering knowledge that would better prepare them for our changing world. If some training authority were returned to the graduate student, some of the conditions creating overspecialization may be eliminated. In light of the Society's concerns in this area, ACS has encouraged NSF to revisit the current balance of support between research assistantships and fellowships/traineeships.

While change is necessary to increase the versatility of graduate programs, special care must be taken to not lose excellence or the purpose of the advanced degree. The ACS concurs with the additional recommendations made within the Report that maintaining local initiative, controlling time to degree, and attracting a diverse group of individuals into the scientific and engineering disciplines are important.

Looking now at the second overarching set of recommendations that focus on providing better information and guidance on career opportunities, the ACS supports these heartily. Combining improved information availability with increased autonomy in the graduate research experiences will greatly enhance the productivity of the graduate education system. In particular, market forces will prevail and those faculty who are successful in training students ***and*** providing opportunities for successful careers will attract the best students. Those that take advantage of the students for their own research agendas, without regard to career opportunities, will be unable to continue to attract top quality students.

Providing career information for its members is a priority for the ACS. Thirteen, full-time employees work in the Society's Department of Career Services. At present, the Department offers a unique collection of "hands-on" programs, services, and products specifically designed to assist the professional and economic future of chemists. These services include expert career assistance, employment services, workforce analysis, workshops and presentations, publications, and videos.

Our present efforts are effective, but limited in their ability to meet the increasing need. ACS is seeking ways, particularly through the World-Wide-Web (WWW), to take advantage of the ability to electronically disseminate information. For example, the Society is developing an employment database for the chemical sciences accessible through the WWW. The service will be searchable to both members and nonmembers, and by both job-seekers and job-providers. It will provide access to corporate home pages and other career service facilities. The ACS also plans to develop an on-line professional database, complete with resumes. Similarly, the Society is considering the use of WWW and satellite-TV courses to enhance its current career briefs and directory of chemistry-related job opportunities for use by high school, college, and graduate school guidance counselors.

However, these efforts are not enough. Graduate faculty, who are the most influential mentors, need to become cognizant that their responsibilities include career development as well as developing the research potential of their students. This mean that faculty must become knowledgeable in the ways industry functions and its requirements. ACS is beginning to explore what the needs are and what opportunities exist to effectively reach faculty. It is clear that many different modes of communication will be necessary.

The Society would like to express some concern regarding the final recommendation of establishing a national human-resource policy for advanced scientists and engineers. Such an effort would be a formidable challenge and one that would require much thought prior to implementation. As history has demonstrated, the need for scientists and engineers is cyclic and subject to market forces. Further, the need for chemists does not necessarily correlate with the need for mathematicians, or any other discipline with another. These needs are difficult to predict. Additionally, to produce a quality graduate in any discipline takes time. Production is not something you can turn off, and then immediately turn back on again like water from a faucet. While the Society agrees that the goal is desirable, its implementation will be difficult and, if done incorrectly, harmful to the Nation.

The Society believes that the time to earn an advanced degree has become unnecessarily long. Most graduate schools currently have a policy that degrees must be completed within seven to ten years of enrollment. Unfortunately, abuse of these policies exists and could become worse as the number of new students available for graduate school decreases. This problem deserves attention. Options should be studied such as the federal government limiting its support to only those schools that have a stated and enforced policy that a doctorate must be earned by full-time students within a seven-year time-period.

An additional solution could be the establishment of a fellowship/traineeship program that requires a university-provided plan for course work breadth. The awards should be further structured so that they include a time limit (*e.g.*, four years). Extensions would require that the school show the time to degree for all doctoral students is less than 5.5 years.

The American Chemical Society, comprised of over 150,000 chemical scientists and engineers has been honored to share its thoughts with you on this vitally important issue. We hope our comments are useful, and are always prepared to assist you in your endeavors as warranted.

Mr. BARTLETT. Thank you very much.
Dr. Miller?

STATEMENT OF DR. JOSEPH MILLER, SENIOR VICE PRESIDENT, CENTRAL RESEARCH AND DEVELOPMENT, DUPONT, WILMINGTON, DELAWARE

Dr. MILLER. Good afternoon, Dr. Bartlett. If you have time for one more, I won't take long.

I would like to thank the Committee for their invitation to discuss graduate education today. First, a word of introduction. I am Joseph Miller, an organic chemist, Senior Vice President for R&D at Dupont and Dupont's chief technical officer.

Dupont has $39 billion in sales, with an increasing volume outside the United States. These sales contribute to the $18 billion positive balance of trade associated with the American chemical industry in 1994.

Among our more than 70,000 employees in the United States are 2,500 with doctorates and 2,000 with masters in science and engineering. These products of graduate education are our most valuable contributors, trained in working at the forefront of science and technology, and they are critical to the company's competitiveness in the global marketplace.

Increased competitiveness has required us to compress the transition from graduate school into the industrial laboratory. Previously, a talented new employee often had several years to develop expertise in an area of interest to the company and demonstrate performance as an independent investigator or expert in a core competency. If the educational experience did not quite match our needs, there was time to learn.

Now the demands for increased productivity often require rapid mastery of a new technical area. Here breadth of education is of critical importance as the scientist or engineer so trained is better equipped to deal quickly with new intellectual challenges. The individual who has learned how to learn, whose field of expertise has not been overly constrained, is better prepared for continued intellectual renewal in a multidecade career.

In addition, the broad technical background allows more effective interactions among scientists and engineers and more effective utilization of the many skills and resources found in industrial laboratories. The formation of teams is more natural and communications more efficient.

In past decades, such broadly trained Ph.D.s were often hired into our central laboratory. Some remained there for much of their careers. Most moved into operating units, learning the business-related aspects on the job or through a multitude of training opportunities and internal transfers, dispersed throughout the company and rising in management. They have provided strong scientific and technical skills balanced with marketing, manufacturing, and business expertise at all levels of the organization.

In recent years, such well-rounded doctorates have become rarer. But there are substantial opportunities in both large and small companies for the more broadly Federal educated and adaptable Ph.D.s.

The market for those with doctorates will depend significantly on the nature of their education. We do not favor arbitrary limits on enrollments targeted toward the Ph.D., but rather a broad training which will prepare the degree holder to function in a variety of positions, not just the central research laboratory.

Information should be made available to students and faculty mentors as to possible opportunities. The GOALI program of NSF by supporting exchanges of personnel between academia and industry should facilitate such communications.

Thus we strongly support the COSEPUP report, with its focus on the educational component of the graduate experience. This focus can be enhanced by moving some financial support from research assistantships to fellowships and education training grants. These last categories are restricted to U.S. citizens. They should, therefore, facilitate the recruitment of women and underrepresented minorities, an objective in many activities in industry.

An important perspective in the report is considering graduate research as an educational experience. To this end, granting agencies might weigh the likely education benefits for the student in evaluating research proposals. We feel that a Ph.D. degree with broad training in courses and an intensive two-to-three-year research program would prepare most graduate students for industry. If the research is multidisciplinary, perhaps with more than one research advisor, perhaps with some time in an industrial environment, the benefits should be even greater.

Terminal masters programs primarily devoted to courses but with a cooperative period in industry are appropriate for many industrial positions. A variant of considerable value would combine training in a science with some innate related engineering discipline such as chemistry with chemical engineering.

While the concentration on education in the report is meritorious, we must not neglect the scientific contributions of graduate research. These have been of great importance in industry and will continue to be so. Some additional comments are given in my written testimony.

In the long term, the Nation's support of basic research by government and industry will help to determine the growth of our economy and the generation of new jobs, including those for Ph.D.s.

In closing, I would like to express my appreciation for this opportunity to present some views on graduate education, a topic of great importance to industry. In this time of change, the COSEPUP report provides a thorough summary of significant issues and makes a number of worthwhile recommendations.

Thank you very much.

[The prepared statement of Dr. Miller follows:]

Written Testimony For Basic Research Subcommittee, July 13, 1995

J. A. Miller
DuPont Central Research & Development
Experimental Station
Wilmington, DE 19880-0328

Thank you Mr. Chairman for the invitation to discuss graduate education this morning. First a word of introduction.

I am Joseph A. Miller, Senior Vice President - Central Research & Development and Chief Technical Officer of DuPont. We are a $39 billion company, with an increasing volume of sales outside the United States, contributing to the $18 billion dollar positive balance of payments associated with American chemical industry in 1994. Among our more than 70,000 employees in the US are 2,500 with doctorates and 2,000 with masters in science or engineering. These products of graduate education are our most valuable contributors, trained and working at the forefront of technology and critical to the Company's competitiveness in the global marketplace.

It is with some reluctance that I discuss graduate education as the universities already have too many outsiders commenting on their activities. Still, with fewer opportunities in academia, greater attention to careers in industry is appropriate including the recent changes there.

One change is a more compressed transition between graduate school and the industrial laboratory than in earlier decades. Previously, a talented new employee often had several years to develop expertise in an area of interest to the Company and demonstrate performance as an independent investigator or expert in a core competency. If the educational experience did not quite match our needs, there was time to learn.

Now the demands for increased productivity often requires rapid mastery of a technical area somewhat different from that of the doctoral thesis. Here, breadth of education is of critical importance as the scientist or engineer so-trained is better equipped to deal quickly with new intellectual challenges. The individual who has "learned how to learn," whose field of expertise has not been overly constrained, is better prepared for continual intellectual renewal in a multi-decade career.

In addition, the broad technical background allows more effective interactions between scientists and engineers and more effective utilization of the many skills and resources found in industrial laboratories. The formation of teams is more natural and communications more efficient.

In past decades such broadly trained PhD's were often hired into our central laboratory. Some remained there for much of their careers. Most moved into operating units learning the business-related aspects on the job or through a multitude of training opportunities and internal moves. Dispersed throughout the Company and rising in management, they have provided strong scientific and technical skills balanced with marketing/manufacturing and business expertise at all levels of the organization.

My own experiences in graduate school and at DuPont illustrate just one of the many possible paths available in the past. I took a variety of courses when qualifying for the doctorate at Penn State. Most were in chemistry but a few were in the chemical engineering department. Close relationships between the two faculties aided this crossover.

At DuPont, I have been in 19 positions in 29 years including R&D, manufacturing, planning, and several businesses. The diversity of environments has been endlessly stimulating, requiring continual learning. My present position has the charge to redirect a superb research organization to provide more effective technical leadership for the Company. The diversity of subjects to which I am exposed encompasses many areas in the physical and life sciences, as well selected fields of engineering; a technical smorgasbord.

In retrospect, my diverse graduate training provided the foundation on which I and DuPont have constructed my career. While many changes have occurred in the technical sphere in the past three decades, the need for the broadly trained and adaptable PhD remains.

In recent years such PhD's have become rarer. Specialization is driven by the greater complexity of the science, poorer K-12 and undergraduate preparation as well as the need for research productivity to ensure financial support. There will be a continuing need for some well-educated specialists throughout industry and recruiting is now focused on them as we strengthen our competencies. The concern with this specialization is that it may become an alternative to breadth, with the individual unable to adapt to new technologies.

The greater opportunity is for more broadly educated and adaptable PhD's. The market for those with doctorates will depend significantly on the nature of their education. We do not favor arbitrary limits on enrollments targeted toward the PhD but rather a broad training which will prepare the degree holder to function in a variety of positions, not just the research laboratory.

Information should be available to students and faculty mentors as to possible opportunities. The GOALI program of NSF, by supporting exchanges of personnel between academia and industry, should facilitate such communications.

Thus, we strongly support the COSEPUP report with its focus on the educational component of the graduate experience. This focus can be enhanced by moving some financial support from research assistantships to fellowships and education/training grants. These last categories are restricted to US citizens. They should thus facilitate the recruitment of women and underrepresented minorities, an objective in many activities in industry.

Another important point in the report is viewing graduate research as an educational experience. To facilitate this process, granting agencies may wish to give some consideration to the likely educational benefits for the student in evaluating research proposals.

We feel that a PhD degree with broad training in courses and an intensive 2-3 year research program will prepare most graduate students for industry. If the research is multidisciplinary, perhaps with more than one research advisor, perhaps with some time in an industrial environment, the benefits should be even greater.

Terminal master's programs, primarily devoted to courses but with a short thesis, as in a cooperative arrangement with industry, are appropriate for many industrial positions. A variant of considerable value would combine training in a science with some in a related engineering discipline, such as chemistry with chemical engineering.

While the concentration on education in the Report is meritorious, we must not neglect the scientific contributions of graduate research. These have been of great importance to industry and will continue to be so. Basic research has been essential to the modern DuPont Company and what we have done in-house owes much to academia.

Still, it was pointed out in 1926 by C. A. Stine, then Chemical Director, that university research did not fill all the existing gaps in scientific knowledge of importance to the Company. He suggested "...including in the Chemical Department budget for 1927 an item of $20,000 to cover what may be called for want of a better name, pure science or fundamental research.... The sort of work we refer to is work undertaken with the object of establishing or discovering new scientific facts. It is thus distinguished from what may be called applied research, which applies previous established scientific facts to the solution of practical problems." Out of this vision came the polymer program of Wallace Carothers and much of the DuPont that we know today.

Our synergistic relationship with university research has continued for many decades. More than 60 years ago a chemical laboratory at Notre Dame provided a crucial lead for DuPont's development of neoprene, our first commercially successful synthetic polymer. In the past few years recent contributions from academia have allowed us to improve substantially our neoprene, nylon and polyester processes. These are processes that support businesses that are more than 50 years old. The development of new polymers in our laboratories owes much to current programs in universities.

But Stine's point that universities cannot supply all our needs is still valid. We are establishing fundamental research programs to investigate technical areas which are of critical importance to us. Here, the products of the university graduate schools, both research and students, are essential to these efforts and to our future.

In the long term, the nation's support of basic research, by government and industry, will help to determine the growth of our economy and the generation of new jobs, including those for PhD's.

In closing I would like to express my appreciation for this opportunity to present some views on graduate education. It is a topic of great importance to industry. In this time of change, the COSEPUP report provides a thorough summary of significant issues and makes a number of worthwhile recommendations. The committee and its chairman deserve our gratitude for providing such a fine foundation for discussion of this critical subject.

Thank you.

Mr. BARTLETT. Thank you very much, and thank all of you for your testimony. If I might recognize Mr. Geren for questions at this time, and I will return momentarily well before he finishes.

Mr. GEREN. Mr. Chairman, I don't have any questions.

[Laughter.]

Mr. BARTLETT. Then I will return very quickly.

Mr. GEREN. I thank the members of the panel for their testimony. I think it has been a very illuminating part of this process and helps give balance to the testimony we have had from the people who work in these agencies.

I and other members on this side of the aisle will be prepared to submit written questions to you as we prepare to make the best sense out of what we have heard from the folks in the agencies and what we have heard from you. I do very much appreciate your expert insights. Mr. Chairman, I yield back the balance of my time.

Mr. BARTLETT. Thank you very much.

I do have several questions, but I would like first to recognize Ms. Lofgren.

Ms. LOFGREN. Thank you very much.

First, I would just like to thank all of you for being here. Your written testimony is very helpful, and your oral testimony, and I think it is important for us to think long term about where we are going as a country. Too often we get caught up in the emergencies of the day and that really brings me to a question for Dr. Heindel.

I was interested in your comment, I am not saying I agree or disagree, on whether we should have a plan for the development of human resources. It occurs to me that to some degree America has just been lucky. We have been rich, we have been more prosperous than other parts of the world. We haven't had to pay attention in a real strategic way to being ahead of others.

Now, I am not suggesting that our country is susceptible to the type of planning, for example, that Singapore engaged in. We are too diverse. Thank God we are too unmanageable for that to occur. Yet I also know that if we are looking ahead 15 years and we are looking at how our children are achieving in the fifth grade today, there is only one conclusion we can reach, which is we have got some problems there if we expect those fifth-graders to be rocket scientists.

I am mindful of a client, a legal client I have, gosh, now, 20, 25 years ago. He had done postdoctoral work in physics and I couldn't even understand what he had done. He was from Upper Volta. And this guy was a genius, and he was wanted by numerous industries in this country and the Defense Department had an interest. He was one of those people who was one of a handful in the world who really was as good as he was, and he wanted to stay here because there was nothing for him to do in Upper Volta. I think it was particle physics of some nature.

That is less true today than it was 25 years ago. There are emerging industries in Taiwan and India and China, and so to the extent that we are able to attract the very top students of the world. That is going to be less true in 15 years than it is today.

I am just sort of wondering what you think in terms of your comment that we shouldn't engage in human resource planning. What

do you mean by that? What should we be doing, given the demographic factors that are facing us?

Dr. HEINDEL. I meant that I didn't believe there was a case that you could make for a numbers game when it comes to human resource planning. I don't disagree with you that there is a need for an outreach to minorities and underrepresented populations, but we are already doing that with a pretty good degree of effectiveness, with all sorts of summer undergraduate programs, with summer high school programs.

NIH, for many years, has had a program to bring students to high school level and to cooperative projects in research universities. We have got programs in place, not those that we talked about today, to reach out and make that sixth- or seventh-grader interested in science.

Where the American Chemical Society is worried about the cosmic plan is the inability to project absolute numbers of needs for various kinds of doctoral grads. I think we should particularly steer away from that, but I don't think there is any reluctance. There is a necessity for planning better quality science in capturing of students at lower degree levels.

Ms. LOFGREN. So you would agree with Dr. Wrighton's comment that the country won't be worse off if we have more educated people? I like that.

Dr. HEINDEL. I think we have to have them be willing to accept a broader need for their talents. We have unfortunately traditionally turned out students who believe that when their primary research tool was a hammer, all problems resembled nails, and they've got to be willing to go out and be in tech sales, tech service. That is our challenge, to give them that breadth.

Ms. LOFGREN. By the way, Mr. Brown would appreciate and I would very much appreciate and I am sure the whole Committee would appreciate getting later in writing the tracking you have done on the employment of postdocs. There is a data deficit here, at least on the Committee. It may not be true in the world, and I think if we know what is happening now, it helps us.

Dr. HEINDEL. May I say quickly that some of the surprising things in last year's graduating class, over 50 percent of the chemistry Ph.D.s went into postdocs. That is up from something like eight or nine percent a decade ago.

So there is an incredible postdoc bubble soaking up our grads, which means that the employment percentage looks high.

The other major frightening statistic is how many people are still on postdocs eight, nine years after receiving their Ph.D. The cohort that graduated '87 to '88 in chemistry, about 11 percent are still out there in unstable, temporary postdoc positions.

Ms. LOFGREN. Thank you very much.

Mr. BARTLETT. Thank you very much.

You just mentioned George Brown. I was going to mention him. He is a Committee treasure, and I just wanted to express how much we appreciate him on our side of the aisle also. He has so much enormous institutional knowledge and good common sense that he is really appreciated.

Dr. Walker mentioned the problem of teaching versus research in our institutions. I remember my graduate professor in the univer-

sity mentioned one day one of the great rewards of teaching and that was that in this life this is the closest that you could come to immortality because you live on in your students.

I thought, what a great philosophy it was. He was something of a philosopher as well as a great scientist. I remember one day I came in one day and he asked, "Well, Roscoe, what do you know today?" I said, "Gee, I don't know much today." He said, "We probably can give you a Ph.D. then." And that is something that so few people recognize, that one of the requirements for a Ph.D. is to recognize how much there is to learn and how little of that you have learned.

Over the door of most academic institutions is an unwritten motto that says "publish or perish." This has given rise to what many think. As a matter of fact, there was a TV segment on this not very long ago, pointing out some of the teaching problems in some of our best institutions.

I remember when I got my doctorate that the department head had the notion that he should put his best teachers teaching the freshman courses, that the graduate students were going to learn in spite of the teacher. I wonder, are we doing better at a balance between teaching and research in our premier institutions? Yes, sir?

Dr. WALKER. I think for a variety of reasons we are making progress there. I think that, first of all, the public scrutiny and the public discussion of that has caused us not only to respond as you would expect us to respond, that they are always connected and that teaching and research are just intertwined paths to learning.

But it has made us relook at our own priorities and how we assign responsibilities. I come from a tradition also where the best researchers were often given the opportunity to teach physics for elementary school teachers. These elementary school teachers are going to get our children when they are six, seven, eight years old, and if they don't do the job, we have got an impossible task in front of us 12, 15 years later.

So I think that with regard to departmental awards, with regard to the priorities in the university, certainly the graduate school has traditionally been an area, an arena that is removed from an individual discipline, but looks overall at the scholarship of the university.

I think the graduate school has an important role to play here and will be empowered, I think, by reports like the COSEPUP report to make sure that at the graduate level and at the undergraduate level because our graduate students get a lot of training and exposure and are role models for undergraduates. Especially in areas where people are underrepresented, you can make an important difference.

Mr. BARTLETT. Thank you.

I am glad that we are having a focus on quality of teaching. That hasn't been one of the criteria for selecting faculty members for our premier institutions. I hope—it may be down your list a little bit—at least I hope it is on the list of selecting faculty members for your institutions.

Our first two speakers mentioned in different ways the industrial-university partnership, and I was reminded of a focus on that

when some representatives from Johns Hopkins University came with a problem that the government had told them that they could not apply any more for funds to build facilities, that they needed to build the facilities themselves for research and that then they could write off the cost of those facilities as overhead as they used them through the years in conducting their research.

Then there was some taking advantage of the kinds of openness that was available in using the funds that were provided by government in one of our Western institutions, and the solution of Congress was that we would just fix that by putting a cap on the percentage of overhead that could be included in the grant. When they did that for Hopkins, there wasn't enough money there to pay for the facilities that the government said you've got to build yourself and then you can write it off as overhead.

I asked them, "How much of your funding is supported by the Federal Government," and their response was, "Over 90 percent."

My immediate response to that, and I am not talking now about the very premier, really premier institutions which take the money that is appropriated by the Congress and award it to students and institutions and so forth. I am not talking about the institution of which I am a member, the Congress. You know, government in terms of the Congress can be enormously arbitrary and capricious, and I am concerned that 90 percent of all of our research dollars for many of our institutions come from government.

When we are talking about an industrial-university complex, I wonder what your thoughts are that maybe the proper role of government is providing an environment in which our institutions, our research institutions and our industrial institutions and so forth, can be incented to provide more of their money to support research, to support education, maybe even a total writeoff against the taxes that they pay.

Are you concerned that 90 percent of all the research dollars in the country come through the government? By the way, as you know very well, there is no such thing as Federal dollars; they either took it from the hardworking American worker or they took it from a business or they borrowed it from our children and our grandchildren. There is no such thing as a Federal dollar.

Your thoughts about the desirability of diversifying the source of funding for research and graduate training by having the government create an environment in which there are more incentives for contributions to this from philanthropists, from industry and so forth? Any of you?

Dr. WRIGHTON. I will be happy to take a crack at that. I was a member of the faculty and later a member of the administration of the Massachusetts Institute of Technology, where we in fact founded one of the leading sets of partnerships with major industry, and those turned out to be very rewarding relationships, on a variety of levels, not simply to provide research funding for individual projects but also to engage the industry in true partnership in defining educational and research programs more broadly.

One of the programs that was inspired just before my tenure as provost was the leadership in manufacturing program, which involved about a dozen major U.S. manufacturers together with MIT, crafting a curriculum to provide experiences in manufacturing.

That turned out to be a wonderful partnership, true in every sense of that word. The industry participants viewed it as much as their program as the MIT program. It is not that the government necessarily needs to provide all the incentives, is my bottom-line point. I think within the universities we have our role to play in providing incentives to faculty and students to be encouraged to participate, and I think there are ways of doing that, and I look forward to working on those kinds of programs at Washington University, which, you know, has one of the strongest partnerships with the Monsanto Corporation.

Mr. BARTLETT. Thank you. Other comments? Yes, sir?

Dr. MILLER. We at Dupont work very closely with universities. Many of our most important products today were born out of inventions that were made in collaboration with universities. We have supported capital needs at universities. We don't believe in contract research. We believe, however, it is important to support basic research in areas of relevance and interest to us, and our program in collaboration with the universities has expanded because we can't get all of the basic research we need to get done within our own industrial laboratories because our businesses have become very complex.

But we feel very strongly about supporting education there and education at all levels, and have for many, many years, and we see our program expanding naturally in support of basic research at universities.

Mr. BARTLETT. I am pleased at this. Our Congress has in the recent past had the notion that a productive kind of partnership between the government and industry was to require basic research institutions to become involved with industry and manufacturing.

I just have the feeling that basic research—in other words, I have been in both areas, I have been very fortunate, I have been awarded 20 patents and I've made work for major industries. I just feel that basic research, you know, you seek knowledge for the sake of knowledge, and I have even heard such thoughts here as that the responsibility of the government is to promote directed basic research. I think that is an oxymoron.

I don't understand if it's research, and I say, "What do you mean by that?" They say, "Well, we want to support research that has societal payoff." I say, "What societal payoff do you imagine Madame Curie thought of when she made her first early investigations?"

I think research will have the greatest society payoff when we seek knowledge for the sake of knowledge and we have no constraint on where the search for knowledge leads us. Do you generally concur with that philosophy?

Dr. HEINDEL. May I comment briefly on that? I would refer you to an oft-repeated and oft-published speech of Roland Schmitt, a retired president of Renssalaer, given in many public arenas, in which he makes the case that you are unlikely to discover some fundamental, basic science principle when looking for an applied one as you are to discover something commercially useful when looking for something basic."

You have got to remember I wear another hat. I teach at a second-tier institution, at Lehigh. Thirty percent of our money comes

from the Federal Government; the rest comes from industry. In my mindset, where we're going to draw the line between basic and applied research is going to be different from Dr. Wrighton's, to my right. We do a fair amount of industrial contract work, and, boy, does it prepare the students well for jobs in the real world. It also prevents them from becoming narrow and entrenched, because frequently the projects are only one year's duration. So a student gets to learn two or three different things on the way to achieve it.

But Roland Schmitt makes the point that Pasteur, when employed by the French Vintner Association to discover the reason wine turned tart with age, fundamentally discovered the field of microbiology.

He gives the example of an AT&T employee named Jansky, who, trying to discover the source of static in long-distance phone lines, ran a wire through a Kansas cornfield and, in so doing, discovered the source of static being from the heavens and launched the field of radio astronomy.

So we have the to be a little careful on where we draw this basic and applied line. We can still contribute to the total knowledge pool sometimes when we really have a mission that we are involved in.

Mr. BARTLETT. There is a TV ad on the discovery of polycarbonates, the role of serendipity. It occurs in research. It occurs in science. I think what you are referring to is the kind of open-mindedness, the willingness to explore opportunities that unexpectedly develop whether you are pursuing applied research or whether you are pursuing basic research. Anyone else have a comment in this area?

Dr. Walker?

Dr. WALKER. The only pause I have, first, let me say what I think, I guess are the positives. I think if you have diverse sources of funding, there can be a certain enrichment there. The patrons have different perspectives, and will bring different kind of priorities, perhaps. I think that is to the good.

What I am concerned about is if one assumes that another part of our country will come in and take over the support and it doesn't really manifest itself, for a variety of other reasons. So that is the only caution.

Mr. BARTLETT. That government needs to be there as a safety net? This is very consistent with the fundamental philosophy that I have—it is not mine, it started a long time ago by Abraham Lincoln—which said that government should do for its citizens only what they cannot do for themselves. I have no problem with stating that.

I have two brief questions that I want to explore with you. One is a problem I have had for quite a while. The focus of the hearings today have been on graduate education and here there is no question that we have the premier institutions in all the world and the top graduate students from all the world tend to come here.

Recognizing that, one wonders why we have another problem. I worked for IBM for eight years and then left about 20 years ago, and while I worked there, we recognized that unless we did something in this country to change the quantity and quality of graduates that we were producing in science, math, and engineering, that IBM could no longer maintain its superiority in computers, the

United States was not going to maintain its superiority in computers. Japan was the country that was producing the quality and quantity of scientists, mathematicians, and engineers who were likely to become dominant in this era.

That pretty much happened. I am delighted, with Sematek and some recent advances, that we are recapturing some of that cutting-edge technology in this country.

But, you know, what is happening in this country whereas at the graduate level we clearly have the premier institutions in all the world, how can we fail to produce the kinds of scientists, mathematicians, and engineers that drive our industrial complex at the lower levels?

This is a reality that I think most of us recognize. Is there some thought being given to that? I know Newt Gingrich, in his description of some of the factors that cause us to stop and take notice, one of them is that we are—and I have taught for a while at a community college, and this is literally true—we are graduating 18-year-olds who literally cannot read their diploma.

What is happening? What do we need to do about it? Have you insights? If you have insights after thinking about it, we would be very happy to have those submitted for the record, because this is a problem which is just kind of astounding, that we should do such a phenomenal job at the graduate level and to fail so utterly at the level that we are producing the men and women who are driving our industry. What's wrong? What can we do about it? Yes, sir?

Dr. HEINDEL. Let me make a brief comment on that. I have become increasingly aware that there is a tendency on the part of much of our student generation to want to get out into the real world. A sizable slug of the high school graduating class that could go on to college just wants to get out and work. "I am tired." And, boy, do you find those undergraduates at the bachelors level.

Talent that could go on and receive more training and become more productive wants to leave and get on with employment.

I think the need in all of our disciplines is to focus a little more on continuing education, taking that person on the job and helping them acquire the skills, talents, leadership through interaction with universities. I think satellite education is an excellent way to do this, and I see some companies taking leadership positions.

We just signed a contract with Merck to upgrade a group of minority employees to technician status. They are just high school graduates. It is going to be essentially an interactive satellite degree to make them process technologists in fermentation process lines.

So, some companies are paying attention to the need to take the talent that has gotten into the first entry-level position and build them beyond that.

Mr. BARTLETT. I am very pleased that industry is helping to correct a systemic problem that exists. I am concerned when our students spend half the hours of our economic competitors in science, math, and engineering. I am concerned when our students will spend more time seeing murders on television than they will doing deciphering in their classrooms.

In a small way, I try to do something. I support the Superconducting Super Collider. I support the space station be-

cause I think we need to have something as a country to look to to feel good about, to feel proud about. I think we need to have something that captures the imagination and inspires our young people to say, "Gee, that's challenging. That's fun. I want to be a part of that."

You know, I am challenged by the fact that we could do the kinds of things that we might have done with the Superconducting Super Collider. We might have provided the missing evidence that people like Stephen Hawking need. He is doing what to me is a very exciting thing. He is trying to mathematically bring together, tie together in a consistent kind of a way, in a unified way some of the great mysteries of the universe.

I think that is exciting, and I think that we have an obligation to convey that excitement to our young people who don't see excitement there. They don't see it in the laboratory, but they see it in front of a judge in a courtroom. You know, I just think that we need to do a number of things to inspire our bright young people.

Dr. Walker?

Dr. WALKER. I agree. Also, this may not be something that everyone can agree to, but I believe that both the high school, primary, and undergraduate levels and at all of those levels, that young people will respond to the expectations we have for them. I think that we have a responsibility, those of us in education, to expect more. We need to do a better job in what we do, but we need to make a clear and consistent message to students that they have certain responsibilities, also, and we expect more of them.

Mr. BARTLETT. Just one last question and observation. Both Dr. Heindel and Dr. Miller mentioned the problem of focus versus depth. Knowledge is expanding exponentially. It is impossible to know enough, even about a narrow specialty. But I have the feeling that many of the great problems that we need to solve are not going to be solved so much by the narrowly focused specialist, who more and more tends to publish not for the general audience but for a dozen or two professional elites that are going to be reading his papers.

How do we move so that we have adequate focus on the detail that we need to have and yet we are developing the kind of generalists that can use information from different disciplines to solve something?

You know, I don't think cancer is going to be solved. We need to focus on a number of very specific areas, but I think maybe some of the solutions are going to be because we have some generalists. You know, the renaissance man is vanishing from our society, and you all mentioned that problem. You talked about focus versus depth. What do we do about it?

Yes, sir, Dr. Walker?

Dr. WALKER. I think that encouraging students to work in interdisciplinary teams does a variety of things. It will ultimately expose them to a variety of different disciplinary cultures and will broaden their training when they are not looking, because they will be talking to different kinds of people.

But it may well be that the kinds of problems that we are facing now, while an individual may need breadth, you also need a group of people to come together that have a breadth of training, and I

think at the graduate level we need to make sure that our students have exposure to working in interdisciplinary teams more than we do now.

Mr. BARTLETT. Thank you all very much. I don't need to ask my colleagues if they have any questions.

[Laughter.]

Mr. BARTLETT. Let me tell you what a great privilege this was for me to have the opportunity of dialoguing with some of the leaders in education in our country. Thank you very much for your contributions, and I hope that this kind of dialogue continues because there are some very meaningful questions we need to address.

Thank you very much. We stand in adjournment.

[Whereupon, at 1:30 p.m., the Subcommittee was adjourned.]

APPENDIX

Reshaping the Graduate Education of Scientists and Engineers

Committee on
Science, Engineering, and Public Policy

National Academy of Sciences
National Academy of Engineering
Institute of Medicine

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COMMITTEE ON SCIENCE, ENGINEERING, AND PUBLIC POLICY

Study on Graduate Education

PHILLIP A. GRIFFITHS (*Chairman*), Director, Institute for Advanced Study
ROBERT McCORMICK ADAMS, Secretary Emeritus, Smithsonian Institution
BRUCE M. ALBERTS,* President, National Academy of Sciences
ARDEN L. BEMENT, Basil S. Turner Distinguished Professor of Engineering, Purdue University
ELKAN R. BLOUT, Harkness Professor, Department of Biological Chemistry and Molecular Pharmacology, Harvard Medical School
FELIX E. BROWDER, University Professor, Department of Mathematics, Rutgers University
DAVID R. CHALLONER, Vice President for Health Affairs, University of Florida
ELLIS B. COWLING, University Distinguished Professor At-Large, North Carolina State University
BERNARD N. FIELDS,+ Adele Lehman Professor; Chairman, Department of Microbiology and Molecular Genetics, Harvard Medical School
ALEXANDER H. FLAX, Senior Fellow, National Academy of Engineering
RALPH E. GOMORY, President, Alfred P. Sloan Foundation
THOMAS D. LARSON, Consultant
MARY JANE OSBORN, Head, Department of Microbiology, University of Connecticut Health Center
PHILLIP A. SHARP, Head, Department of Biology, Center for Cancer Research, Massachusetts Institute of Technology
KENNETH I. SHINE,* President, Institute of Medicine
RALPH SNYDERMAN, Chancellor for Health Affairs; Dean, School of Medicine, Duke University Medical Center
H. GUYFORD STEVER, Trustee and Science Consultant
MORRIS TANENBAUM, Vice President, National Academy of Engineering
ROBERT M. WHITE,* President, National Academy of Engineering

LAWRENCE E. McCRAY, Executive Director

Principal Project Staff

MICHAEL McGEARY, Study Director
DEBORAH D. STINE, Senior Program Officer
ALAN ANDERSON, Consultant/Writer

* Ex officio member.
+ Deceased, February 1, 1995.

PREFACE

In 1993, the Committee on Science, Engineering, and Public Policy (COSEPUP) issued a report entitled *Science, Technology, and the Federal Government: National Goals for a New Era* (the *Goals* report), which proposed a framework for federal policy to support science and technology. During the preparation of the report, it became apparent that a complete discussion of the science and technology enterprise would require an examination of the process by which scientists and engineers are educated. If scientists and engineers are to contribute effectively to national, scientific, and technological objectives, their educational experience must prepare them to do so. The present report can be considered a companion volume to the *Goals* report.

Several key questions guided the committee during its initial deliberations:

- What are typical career paths for scientists and engineers, and how have they changed in recent years?
- Given present career paths, what are the most appropriate structures and functions for graduate education?
- How can science and engineering graduate students be prepared for a variety of careers in teaching, industry, government, and other employment sectors, in addition to research?
- Are we producing the right numbers of PhDs?[1]
- What should be the nation's goals for graduate science and engineering education?

[1] Because of the concerns regarding PhD unemployment, the report focuses on the PhD.

In attempting to answer those questions, we found important gaps in our knowledge of employment rates and patterns. It has proved difficult, for example, to determine where PhDs are and what they are doing in nonacademic positions or to determine accurately either unemployment rates of scientists and engineers or the extent of underemployment, especially among recent graduates, because of the lack of timely data. In fact, we were sufficiently troubled by the lack of generally available information to conclude that students', professors', and mentors' lack of accurate, timely, and accessible data on employment trends, careers, and sources of student support is a serious flaw in our education system.

This deficiency makes it difficult for potential and current graduate students to make well-informed decisions as to whether and where to enter graduate school. It also hampers the faculties at our universities in preparing their students adequately for the full range of professional careers in science and engineering. Therefore, the committee faced a dilemma—whether to make recommendations despite gaps in current understanding or to counsel delay until such understanding is attained. It proceeded to make recommendations now because students, universities and colleges, professors, mentors, funding agencies, employers, and others must make decisions today that will affect the careers of science and engineering students for the rest of their lives.

The recommendations in this report reflect a common theme. Many of the job opportunities of the future will favor students with greater breadth of academic and career skills, so the universities and their partners in the graduate-education enterprise should therefore cooperate to broaden curricular options for graduate students.

We hope this report will be useful not only for university presidents, provosts, deans, and others in the decision-making structure of universities, but also for all institutions and individuals who are part of the graduate-education enterprise: federal and state government,[2] industry and business, and faculty, mentors, and students at both the graduate and undergraduate levels.

The committee acknowledges the invaluable information and opinions received from a variety of sources. We convened more than a half-dozen panels of experts from academe, government, industry, foundations, and other sectors. The panel members are listed in Appendix E. A call for comments to scientists, engineers, administrators, students, and educators across the country drew more than 100 thoughtful replies, many of them reflecting exceptional care; some correspondents even conducted informal surveys within their own institutions. Those responding to the call for comments are listed in Appendix D and their thoughtful responses are provided in Appendix F. In addition, Appendix G summarizes a survey we sent to graduate students asking what information they need to make decisions. The committee also made use of continuing work by the National Research Council's Office of Scientific and Engineering Personnel.

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[2] There is a lack of adequate information about educational and funding activities at the state level. The states have supported graduate education for many years, and a number of state governments and agencies have initiated innovative ways to broaden graduate education through interactions with industry, government, and community groups.

The production of the report was the result of hard work by the committee as a whole and by the extra effort of the Guidance Group (consisting of Arden Bement, Mary J. Osborn, David Challoner, Alexander Flax, and me), which convened between regular committee meetings. The project was aided by the invaluable help of COSEPUP professional staff: Michael McGeary, study director, who provided research and analytical support, as illustrated in Appendixes B and C and Chapter 2, and drafted major portions of Chapters 3 and 4; Deborah Stine, senior program officer, who managed the committee's outreach efforts and contributed in a major way to Chapter 2; Alan Anderson, consultant/writer, who helped draft and revise the text throughout the project; and Lawrence McCray, executive director of COSEPUP, who oversaw the committee's activity. Wise guidance was provided by Philip M. Smith as a consultant. National Research Council staff members Dimitria Satterwhite, Jeffrey Peck, and Patrick Sevcik ably assisted the project. The committee also thanks its diligent editor, Norman Grossblatt.

PHILLIP A. GRIFFITHS
Chair
Committee on Science, Engineering, and Public Policy

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EXECUTIVE SUMMARY

FRAMING THE ISSUE

Scientists and engineers with PhD and other advanced degrees play a central and growing role in American industrial and commercial life. The traditional process of graduate education to the doctoral level, organized around an intensive research experience, has served as a world model for the advanced training of scientists and engineers.

Graduate education is basic to the achievement of national goals in two ways. First, our universities are responsible for producing the teachers and researchers of the future—the independent investigators who will lay the groundwork for the paradigms and products of tomorrow and who will educate later generations of teachers and researchers. Second, graduate education contributes directly to the broader national goals of technological, economic, and cultural development. We increasingly depend on people with advanced scientific and technological knowledge in our collective efforts in developing new technologies and industries, reducing environmental pollution, combating disease and hunger, developing new sources of energy, and maintaining the competitiveness of industry. Our graduate schools of science and engineering are therefore important not only as sources of future leaders in science and engineering, but also as an indispensable underpinning of national strength and prosperity—sustaining the creativity and intellectual vigor needed to address a growing range of social and economic concerns.

As we approach the 21st century, our graduate schools face challenges both within and outside the academic setting. Many disciplines of science and engineering are undergoing rapid and pervasive change, and many aspects of modern life are increasingly dependent on emerging technologies and the scientific frameworks from which they evolve. New national-security challenges, expanded economic competition, urgent public-health needs, and a growing global awareness of environmental deterioration bring new opportunities for varied careers in science

and engineering. We expect our graduate scientists and engineers to continue the expansion of fundamental knowledge and to make that knowledge useful in the world. A world of work that has become more interdisciplinary, collaborative, and global requires that we produce young people who are adaptable and flexible, as well as technically proficient.

A TIME OF CHANGE

The US system of graduate education in science and engineering is arguably the most effective system yet devised for advanced training in these fields. By carrying out graduate education in institutions where a large portion of the nation's best research is done, the universities have created a research and training system for scientists and engineers that is one of the nation's great strengths.

The present US system of graduate education evolved when the demand for research was either stable or rising. The national-security demands of the Cold War and domestic priorities, such as health, stimulated and supported a strong science and technology infrastructure, including graduate education. Our dominant economic and technological position in the world allowed us to exert clear international leadership and permitted us to influence both the progress of science and the rate of technology development and introduction.

That situation is now changing. The end of the Cold War, the rapid growth of international competition in technology-based industries, and a variety of constraints on research spending have altered our market for scientists and engineers. Furthermore, the United States has traditionally opened its doors to students from other countries. In recent years, the number of foreign science and engineering students enrolled in US graduate schools and the number receiving PhDs have risen unusually rapidly.

The demand for scientists and engineers has remained strong. However, there are indications that there is a slowdown in the growth of university positions and that we can expect a fundamental change in science and engineering employment—a reduction in the demand for traditional researchers in some fields. This employment situation has already contributed to a frustration of expectations among new PhDs. Major industrial sectors have also reassessed their needs and reshaped their research, development, and business strategies. And new research and development needs have arisen in emerging production, service, and information enterprises. The increasing rate of change suggests a need for scientists and engineers who can readily adapt to continuing changes.

Government laboratories and other facilities are also undergoing change. In some instances, research and development foci are shifting. In others, government and its contractor scientists and engineers are being challenged to build linkages with industry and universities. Some departments and agencies are reorganizing and shrinking. Moreover, government spending on research and development is expected to be constrained in the next few years. That places direct pressure on research and development performed by universities and government and indirect pressure on research and development performed by industry under government

contracts.

Hence, the three areas of primary employment for PhD scientists and engineers—universities and colleges, industry, and government—are experiencing simultaneous change. The total effect is likely to be vastly more consequential for the employment of scientists and engineers than any previous period of transition has been. Some believe that the nation's teaching institutions are entering a period when the number of new PhDs should somehow be capped (we return to this point later). Although many recent graduates are frustrated by their inability to find basic-research positions, it appears that the growth in nonresearch and applied research and development positions is large enough to absorb most graduates. However, such employers complain that new PhDs are often too specialized for the range of tasks that they will confront and that they have a difficult time in adapting to the demands of nonacademic work.

A broader concern is that we have not, as a nation, paid adequate attention to the function of the graduate schools in meeting the country's varied needs for scientists and engineers. There is no clear human-resources policy for advanced scientists and engineers, so their education is largely a byproduct of policies that support research. The simplifying assumption has apparently been that the primary mission of graduate programs is to produce the next generation of academic researchers. In view of the broad range of ways in which scientists and engineers contribute to national needs, it is time to review how they are educated to do so.

The approach that is presented in this report is based on reshaping the current PhD experience and improving students' ability to make good career choices. Alternative approaches were examined during the study but were not endorsed. One would be to control graduate enrollments directly, presumably on the basis of expected employment needs. Among the problems with this approach are the questionable reliability of employment forecasts and the practical difficulty of implementing it. Another strategy would be to create a new type of degree—a "different doctorate," perhaps—that entails less intensive research experience and is intended to prepare students for nonresearch careers. Employers told us, however, that they value the requirement for original research that is a hallmark of the PhD, and we see little demand for a hybrid degree. Our approach, we believe, will make the current system self-adjusting at a time when change is certain but the nature of the change cannot be predicted.

SUMMARY OF RECOMMENDATIONS

The process of graduate education is highly effective in preparing students whose careers will focus on academic research. It must continue this excellence to maintain the strength of our national science and technology enterprise. But graduate education must also serve better the needs of those whose careers will not center on research. *More than half of new graduates with PhDs*—and much more than half in some fields, such as chemistry and engineering—*now find work in nonacademic settings*. This fraction has been growing steadily for 2 decades.

We recommend that the graduate-education enterprise—particularly at the department

level—implement several basic reforms to enhance the educational experience of future scientists and engineers who will work in either academic or nonacademic settings. If programs offer a wider variety of degree and curricular options that are valued by their faculty, students will be better served. In addition, we have an obligation to inform graduate students accurately and explicitly about career options so that they will be able to make better educational choices, formulate more realistic career expectations, and achieve greater satisfaction in their careers while contributing more effectively to fulfilling national goals.

In summary, the future PhD degree would be different—an improved version of the current degree. It would retain the existing strengths—especially with regard to leading to careers in academic research—while substantially increasing the information available, the potential versatility of the students, and the career options afforded to them by their PhD education.

General Recommendation 1: Offer a Broader Range of Academic Options

To produce more versatile scientists and engineers, graduate programs should provide options that allow students to gain a wider variety of skills.

Greater versatility can be promoted on two levels. On the academic level, students should be discouraged from overspecializing. Those planning research careers should be grounded in the broad fundamentals of their fields and be familiar with several subfields. Such breadth might be much harder to gain after graduation.

On the level of career skills, there is value in experiences that supply skills desired by both academic and nonacademic employers, especially the ability to communicate complex ideas to nonspecialists and the ability to work well in teams. Off-campus internships in industry or government can lead to additional skills and exposure to authentic job situations.

To foster versatility, government and other agents of financial assistance for graduate students should adjust their support mechanisms to include new education/training grants to institutions and departments.

Most federal support for graduate students is currently provided through research assistantships. Research assistantships are included as parts of grants that are competitively awarded to individual faculty members to support their research. The grant funds are then used to provide stipends to the students in those faculty members' laboratories. Such assistantships offer educational benefit in the form of research skills to the students who work on the faculty members' projects. The needs of funded projects rather than the students' educational needs, however, have tended to be paramount in guiding the students' work.

We recommend an increased emphasis on education/training grants, an adaptation of the training grants awarded by the National Institutes of Health and other agencies. These grants

would be awarded competitively to institutions and departments. Evaluation criteria would include a proposer's plan to improve the versatility of students, both through curricular innovation and through more effective faculty mentoring to acquaint students with the full range of future employment options.

While urging that the nation's overall support for PhD students be maintained as a sound investment in our future, we recognize that a heightened emphasis on education/training grants could reduce the funds available for research assistantships.

In implementing changes to promote versatility, care must be taken not to compromise other important objectives.

Modifying graduate programs to enhance versatility will require care and imagination. Change should be compatible with

- *Maintaining local initiative.* We envision change that comes from local institutional initiatives and that shows considerable local variation. Each program should build on its own strengths and interests.
- *Maintaining excellence in research.* A continuing goal of graduate education is the preparation of students who will dedicate themselves to careers in research. The reforms suggested here are not intended to alter that goal. Instead, we envision complementary steps designed to reflect all employment opportunities—in both the research and the nonresearch sectors. Nor do we espouse what some call "vocationalism"—setting each student on a particular career track and "training" him or her in a narrow specialty. We need instead an educational system that prepares students for a central feature of contemporary life: continuous change.
- *Controlling time to degree.* The time to degree and, more important, the time to first employment are steadily lengthening and are already too long. We believe that it is possible to foster versatility without increasing the time that graduate students spend on campus. Although long times to degree are often decried, universities have not generally made the disciplined effort needed to shorten them. One important step toward shortening the time to degree is to ensure that educational needs of students remain paramount. *The primary objective of graduate education is the education of students.* The value of such activities as working as highly specialized research assistants on faculty research projects and as teaching assistants should be judged according to the extent to which they contribute to a student's education. A student's progress should be the responsibility of a department rather than of a single faculty member; a small supervisory group (including the student's adviser) should determine when enough work has been accomplished for the PhD degree. Each institution is urged to set its own standards for time to degree and to enforce them.
- *Attracting women and minority-group members.* It is essential to attract a fair share of the most talented students to each discipline in science and engineering, irrespective of their sex or ethnic backgrounds. Where it appears that the number of women and minority-group members is low in particular fields, deliberate steps should be taken to deal with real and perceived barriers to full participation.

General Recommendation 2: Provide Better Information and Guidance

Graduate scientists and engineers and their advisers should receive more up-to-date and accurate information to help them make informed decisions about professional careers; broad electronic access to such information should be provided through a concerted nationwide effort.

The burden of learning about realistic career options should not be left to students themselves. We recommend the establishment of a national database of information on employment options and trends. This information, intended for use by both students and their advisers, should include, by field, data on career tracks, graduate programs (including financial aid), time to degree, and placement rates. Departments should track information on their students—not only those who go into universities and 4-year colleges, but those who go into industry, government, junior and precollege education, etc.

The rapid development of the Internet makes it possible to adhere to two important principles in regard to the database: the information can retain a more decentralized, "grass-roots" character than information assembled in central compendiums, and up-to-date information would be readily available to the ultimate consumers—doctoral students, graduates, and faculty advisers.

The National Science Foundation should coordinate federal participation in the database. However, it is preferable to design and manage the database within the academic community itself so that it has accurate, timely, and credible information.

Academic departments should provide the information referred to above to prospective and current students in a timely manner and should also provide career advice to graduate students. Students should have access to information on the full range of employment possibilities.

Advice for students should be improved by a systematic tracking of the employment path of each department's graduates and by use of the national database recommended above.

In the past, when students expected to become professors, graduate school was usually seen as a step on a simple career ladder. We are concerned that this concept is still held in some places. Departments should help students to regard their progress through graduate school as a journey with branches that require decisions. One decision point is the application stage, when students need more information on job placement, salaries, and unemployment rates in various disciplines to decide whether and where to enter graduate school.

Students should be encouraged to consider three alternative pathways at the point when they have met their qualifying requirements.

At the beginning of the research phase, departmental advisers should help students to

choose among three distinct options: first, to stop with a master's degree, in light of their aspirations and projected employment demand; second, to proceed toward a PhD and a position in research; or third, for a student interested in working in nontraditional fields, to design a dissertation that meets high standards for originality but requires less time than would preparation for a career in academic research. We believe that the first option is typically undervalued and the third option often neglected.

The National Science Foundation should continue to improve the coverage, timeliness, and clarity of analysis of the data on the education and employment of scientists and engineers in order to support better national decision-making about human resources in science and technology.

In preparing this report, we discovered a lack of the timely and relevant information that students, advisers, and policy-makers should have. The National Science Foundation should seek to improve timeliness, increase detail on nonacademic employment (which now occupies most new scientists and engineers), and support extramural research on actual career patterns in science and engineering.

General Recommendation 3: Devise a National Human-Resource Policy for Advanced Scientists and Engineers

A national discussion group—including representatives of governments, universities, industries, and professional organizations—should deliberately examine the goals, policies, conditions, and unresolved issues of graduate-level human resources.

In preparing our last report, *Science, Technology, and the Federal Government* (COSEPUP, 1993), we found that no coherent national policy guides the education of advanced scientists and engineers, even though the nation depends heavily on them. At present, there is neither the conceptual clarity nor the factual basis needed to support a coherent policy discussion. We are concerned that many prevailing views are obsolete or are quickly becoming so.

As a starting point, the agenda for national discussion might include national goals and policy objectives, the relationship between the process of graduate education and employment trends, and difficult current issues (such as time to degree and sources of new students) on which opinions diverge.

MAJOR RELATED ISSUES

Two other issues were discussed at some length by the committee and committee witnesses: the relationship between supply of and demand for PhDs in science and engineering and the impact of current high enrollments of foreign citizens. We do not offer recommendations on either issue, but we discuss both in Chapter 4. We present here a brief summary of the discussions.

Is There an Oversupply of PhDs?

The committee is not convinced that the current low and stable unemployment rates among scientists and engineers mean that the system is working as well as it should. In fact, there are indications of employment difficulties, especially among recent graduates. During the course of our study, we often heard concerns that we are producing too many PhDs. Reliable information is scarce, and conditions vary greatly with field, but we report three summary observations:

- *There seem to be far more seekers of jobs as professors in academe and as basic researchers*[1] *than there are available positions. This situation is the basis of the frustrated expectations of new PhDs.*
- Overall unemployment rates for recent PhDs have remained very low (although the 1994 survey showed a small rise). That implies that steady expansion in applied-research and nonresearch employment has ultimately provided jobs for most of the still-growing cohort of PhD graduates.
- There are some worrisome indicators of weakness in the market, such as substantially longer delays in initial placement of new graduates, the fact that some graduates are employed in positions that do not require a PhD, and the possibility that they are taking postdoctoral assignments only in hopes of better positions when employment conditions in research are brighter.

Nevertheless, we see no basis for recommending across-the-board limits on enrollment, for three reasons. First, conditions differ greatly by field and subfield. Second, we believe that an extensive, disciplined research experience provides valuable preparation for a wide variety

[1] However, this situation does not mean that graduate scientists and engineers can no longer do research. In terms of primary work activity, the share of positions in applied research and development is increasing. It is just that the share of people going into management of research and teaching is declining.

of nontraditional careers for which scientific and technical expertise is relevant. Third, limiting actions would have little immediate aggregate impact even if they could be orchestrated effectively. Instead, we believe that our recommendations of greatly improved career information and guidance will enhance the ability of the system to balance supply and demand. When the employment situation is poor, better-informed students will be able to pursue options other than a PhD; when the market is expanding, students will be able to move more flexibly and rapidly in the direction of employment demand.

Foreign Students

The numbers of science and engineering students and PhDs who are foreign citizens are rising rapidly. The views we encountered about that situation are mixed. Some view it positively, arguing that universities benefit by having foreign graduate students help with research and teaching, that employers benefit by finding the most highly qualified PhDs, and that to compete in a global economy US universities and industries must be able to recruit the best talent available. Others are calling for limits on the numbers of foreign students, arguing that large numbers of foreign citizens compete with US citizens for jobs (which might explain part of the employment problems of recent years); that foreign citizens who return home might work for our economic competitors; that cultural and language difficulties make foreign students ineffective in the classroom as teaching assistants and limit their ability to succeed in the labor market; and that their presence in large numbers depresses salaries and thereby generates a discouraging market signal for potential American students.

As we argue in Chapter 4, the committee does not recommend limiting the number of foreign students, for several reasons. First, there is considerable anecdotal evidence that the most outstanding foreign PhDs tend to find employment in the United States and make major contributions to our nation. Second, the sharp increase in number of foreign-citizen graduate students seems to have been caused in part by a set of political events that are unlikely to recur as well as by changes in US immigration laws. Third, one cause of the presence of many foreign students is that their home nations have lacked adequate opportunities in both education and employment; the wealth of these nations is now growing, and there is already evidence that some foreign students are finding attractive employment opportunities at home.

To the extent that there is a limit on the number of departmental "slots" for graduate students, of more fundamental importance than the presence of foreign citizens is the fact that the number of American students entering science and engineering has grown only slightly in recent years and is a declining percentage of the total number of PhDs. We suggest that the most appropriate responses to the relatively flat enrollment of American students are to implement the measures advocated in this report (which should improve the responsiveness of the PhD labor market) and to continue efforts to strengthen the teaching of precollege science. Those measures, we believe, would make graduate education more attractive, more effective, and accessible to a larger group of qualified American applicants.

1

The Changing Context of Graduate Education

The American system of graduate education of scientists and engineers,[1] organized around an intensive and realistic research experience, has become the world model for simultaneously conducting basic research and educating graduate scientists and engineers. Scientists and engineers with PhD and other advanced degrees play a central and growing role in American life.

Graduate education is basic to achieving national goals in two ways. First, our universities are responsible for producing the teachers and researchers—investigators in industry or academe who will lay the groundwork for the paradigms and products of tomorrow and who will in turn educate future teachers and researchers. Second, graduate scholarship and research are key contributors to meeting broad national goals of technological, economic, and cultural development. The increase in scientific and technological knowledge and the ways in which that knowledge is applied are fundamental to the pursuit of many general national objectives, including developing new technologies and industries, combating disease and hunger, reducing environmental pollution, developing new sources of energy, and maintaining the competitiveness of American industry.

Persons educated in and part of our graduate education system provide expert service to society via their development of original ideas, which are brought to fruition in teaching, industry, business, and government. Graduate students often go beyond the thinking of their professors and create a new generation of science and engineering thought. The student learns from the professor, but the professor also learns from the student. Our system of graduate education is therefore important both as a source of future leaders in science and engineering and as a source of new ideas. We must maintain the strength of this system to sustain the

[1] Throughout this report, the term *graduate scientists and engineers* refers to persons who have attained a master's or doctor of philosophy degree in science or engineering. *Science* is taken to include the life sciences, physical sciences, social sciences, and mathematics. *Engineering* is taken to include all specialties of engineering.

creativity and intellectual vigor that will be needed in the United States to address a growing variety of social and economic concerns.

The efficacy of our system originated in a series of policy decisions that were prompted by the major role that science and technology had in the outcome of World War II. Among those decisions were the following:

- The public, through a number of government agencies, would assume an important role in funding basic and applied research.
- Through public funding, researchers at universities throughout the country would become major contributors to the nation's scientific research expertise.
- The universities would conduct basic research and the graduate education of scientists and engineers as joint, synergistic activities.

The dual role of the graduate science and engineering enterprise was designed to benefit the nation by educating students through the active conduct of cutting-edge research. According to a report by the National Research Council in 1964, "graduate education can be of highest quality only if it is conducted as part of the research process itself" (NRC, 1964).

By educating students in the context of research, the American system of graduate education has set the world standard for preparing scientists and engineers for research careers in academe, government, and industry. And by attracting outstanding students and faculty members from throughout the world, it has benefited from an infusion of both talent and ideas.

The products of research have contributed abundantly to the health, defense, and well-being of the country, and American has generously supported the education of its scientists and engineers with both state and federal funds and with donations from industry, large nonprofit organizations, and the universities themselves.

> The graduate-education enterprise in the United States is diverse and decentralized. Because of the diversity of missions and agencies participating in higher education, any important changes require cooperative efforts based on a shared understanding.
>
> There are many independent participants, including more than 600 public and private universities and colleges (which offer master's or doctoral degrees in science and engineering), scientific and engineering societies (which help to define what scientists and engineers should know and do), state governments (which provide support for universities), the federal government (which supports research and education), philanthropic organizations, accreditation bodies, the Council of Graduate Schools, the Association of American Universities, and the National Association of State Universities and Land Grant Colleges.

Box 1-1: The Graduate-Education Enterprise

States have the longest tradition of supporting graduate education. Beginning with the Morrill Act of 1862, states funded on-campus agricultural research to serve the public goal of bringing technology to the nation's farmers. Today, by subsidizing tuitions, they have ensured wide access to graduate education at low cost. The state universities and land-grant colleges

subsidize about half the doctoral-degree recipients in the United States and employ the professors who educate them.

Federal support for graduate education of scientists and engineers, a more recent phenomenon, expanded rapidly after World War II with the establishment of the National Science Foundation (NSF), the National Institutes of Health (NIH), and other agencies. Funding for the education of graduate scientists and engineers grew rapidly in the late 1950s after the launching of Sputnik in 1957 and passage of the National Defense Education Act in 1958. The federal government has developed a number of programs for the direct support of graduate education, including fellowships, traineeships, research-infrastructure grants, and institutional development grants.

The number of graduate science and engineering students increased roughly in parallel to the amount of federally funded scientific and engineering research from 1958 to 1988. Between 1958 and 1968, the number of PhDs awarded annually to scientists and engineers tripled to about 18,000. That swift growth lasted until the early 1970s, when national policy changes brought about the curtailment of most federal fellowships and traineeships.[2] Thus, the annual production of science and engineering doctorates peaked at near 19,400 during 1971-1973 and fell to fewer than 18,000 during 1977-1985. The production of PhDs began to rise again in the late 1980s and reached 25,000 in 1993 (see Figure 1-1). Most of the net growth after 1985 was due to an increased number of foreign students with temporary student visas (see Figure 1-2).

> The doctor of philosophy degree is the highest academic degree granted by North American universities. PhD programs are designed to prepare students to become scholars, that is, to discover, integrate, and apply knowledge, as well as to communicate and disseminate it.
>
> A doctoral program is an apprenticeship that consists of lecture or laboratory courses, seminars, examinations, discussions, independent study, research, and, in many instances, teaching.
>
> The first year or two of study is normally a probationary period, during which a preliminary or qualifying examination might be required. The probationary period is followed by an examination for admission to full candidacy, when students devote essentially full time to completing dissertation research. This research, planned with the major adviser and the dissertation committee, usually takes 1-3 years, depending on the field. An oral defense of the research and dissertation before a graduate committee constitutes the final examination.
>
> Source: CGS, 1990

Box 1-2: The PhD Degree

Since the late 1980s, the institutions that conduct research in concert with graduate education have been buffeted by a series of political, economic, and social changes. The end

[2] For example, the NSF training-grant program was terminated, and research fellowships were cut back to 500 (they have since returned to 2,500). Only the NIH's training-grant program was maintained, through the intervention of Congress; but even this program was reduced as overall federal funding for direct support of graduate science and engineering education fell by 80% in the early 1970s.

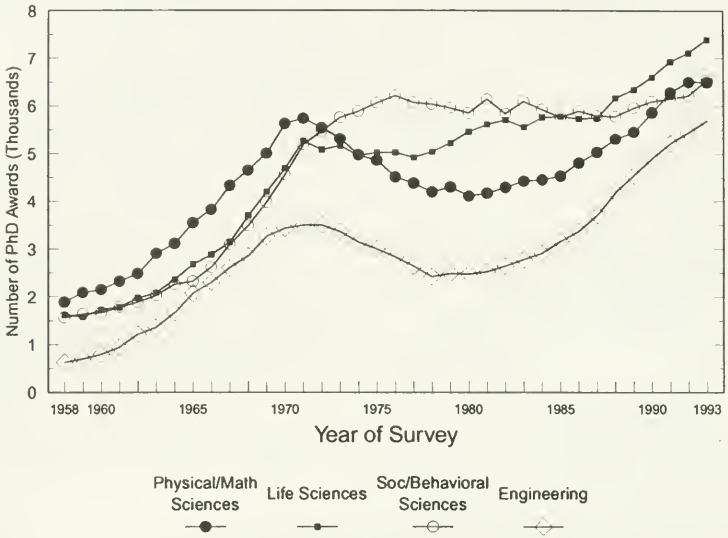

FIGURE 1-1 Number of doctorates awarded by US institutions, by broad field, 1958-1993.

SOURCE: NSF, 1994f:Table 1, for 1983-1993; unpublished "decade" tables, Office of Scientific and Engineering Personnel, National Research Council, for prior years.

NOTE: The physical/mathematical sciences include physics, chemistry, astronomy, mathematics, computer/information science, and environmental (ocean, atmospheric, earth) sciences. The life sciences include the biological, agricultural, and medical sciences. The social/behavioral sciences include the social sciences (e.g., economics, sociology, political science) and psychology. More detailed information on fields of doctorates awarded in 1983-1993 is presented in Appendix B, Table B-20.

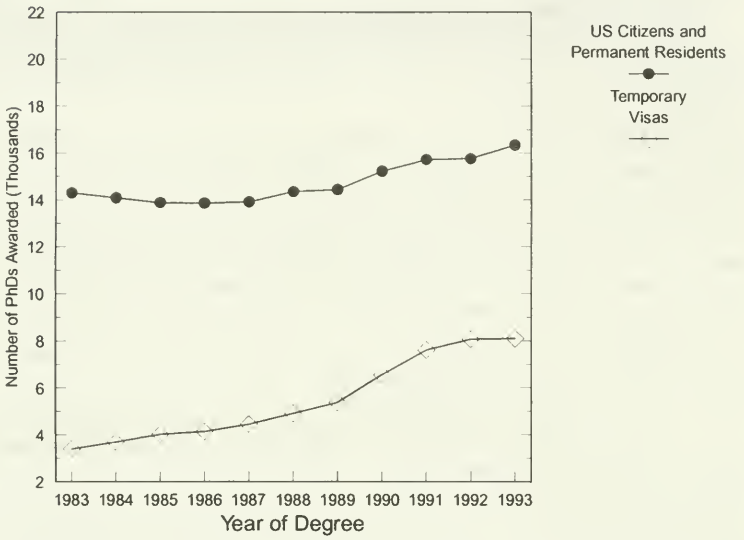

FIGURE 1-2 Trends in citizenship of recipients of doctorates from US institutions, 1983-1993.

SOURCE: Calculated from NSF, 1994f:Table 3.

NOTE: The numbers are based on those whose citizenship was known (between 92% and 98% of each year's doctorate recipients in 1983-1993).

of the Cold War has led to major cuts in defense spending, which are a source of R&D funding.[3] The cuts began in 1987, when, for the first time, the overall increase in federal funding for research stopped growing faster than inflation. Not only have fiscal constraints affected the science-oriented government agencies, but the agencies have responded to political forces by shifting toward an emphasis on "strategic" research that is oriented toward national objectives.

The last decade has seen both a rise in international economic competition and cutbacks in basic research at large industrial laboratories. Industry is said to be hiring fewer scientists and engineers and shifting emphasis toward core businesses; industrial grants to universities, an important source of research funds, are said to be reduced and increasingly directed toward incremental, low-risk programs.

State governments are tightening their budgets, with some public universities experiencing absolute decreases of 20-25% in state funding. That has reduced the ability of state universities to hire scientific and engineering faculty and to fund graduate students. Many state legislators view graduate education as a budget item that must compete with social requirements whose call on the tax dollar is at least as persuasive. Criticisms of faculty productivity are common, as is a general skepticism that the public receives an adequate return on its investment in graduate education. The Maryland General Assembly, for example, has ordered new policies that establish explicit expectations for faculty workload and responsibilities. Furthermore, state legislators have sometimes questioned the benefit of educating graduate students who leave the state on graduating.

Owing to these financial constraints, universities must use more of their own funds to support research, especially for projects considered long-term or risky. And they are less able to offer tenure-track positions to new young faculty.

As the financial support for basic research has plateaued, the graduate-education system has been criticized by the public and Congress for neglecting education and other societal needs. With the end of the Cold War and the growth of global economic competition, the nation's attention has shifted from defense to economic, environmental, and other social concerns: we are faced with the challenge of finding better ways to use natural resources, to produce energy, and to deliver health care, and we need to produce better products and services in an internationally competitive marketplace. The nation also has to deal with crime, violence, and poverty. At the international level, we are concerned with limiting population growth, stabilizing emergent democracies, and fostering appropriate industries in developing countries, as well as with sustaining national security and global economic health. The role of research in addressing those concerns is not nearly as clear to the nation as was its role in winning the Cold War or the "space race."

In the face of these complex societal concerns, scientists and engineers have been challenged to take more active and visible roles in society—roles that require leadership,

[3] Universities became less dependent on Department of Defense (DoD) funding in the 1960s and 1970s. Currently, less than 14% of federal support of R&D in colleges and universities comes from DoD. A major cut in DoD R&D would affect federal funding of universities by only a few percent (Sapolsky, 1994). But this decline in defense R&D would probably be highly concentrated in particular fields (such as aeronautics and oceanography).

cooperation, and flexibility. Society expects them to contribute to new debates on public policy, to improve our competitive position in global markets, to help to create high-value jobs, and to improve the education of citizens at many levels.

To repeat: American graduate schools have done a superb job of preparing young scientists and engineers to become original researchers—to become the scientific and technical leaders of the nation. It is the purpose of this report to examine how well graduate school prepares students to integrate and disseminate their knowledge and apply it to the full range of present societal needs.

2

THE EMPLOYMENT OF GRADUATE SCIENTISTS AND ENGINEERS

2.1 CURRENT EMPLOYMENT CONDITIONS

The economy of the United States is absorbing rapidly increasing numbers of graduate scientists and engineers, but continued growth is less certain.

The number of people with science and engineering PhD degrees from US universities who are working in this country has nearly doubled since 1973, from 220,000 to 437,000 in 1991.[1] Figure 2-1 shows this growth by major field. Currently, more than 25,000 scientists and engineers earn PhDs from US institutions each year, most of whom enter the US labor

[1] National estimates of employment-related characteristics of scientists and engineers used here and throughout the report are from the Survey of Doctorate Recipients (SDR). The SDR is a biennial panel survey of a nationally representative sample of recipients of doctorates in science and engineering from U.S. institutions working in the United States. It is conducted by the National Research Council and has gathered employment related information since 1973 for NSF and other federal agencies. Major changes in survey timing and procedures were made in the 1991 survey that limit the comparability of estimates with those of the 1973-1989 surveys. More vigorous follow-up increased the response rate from 58% to 80%, which reduced nonresponse bias among those outside academia or who had left the country. This should have reduced overestimates of the number of U.S. PhDs remaining in the U.S. and of those employed in academia of perhaps 5% in the earlier surveys. The SDR is described more fully in Appendix C, which has a fuller discussion of changes in the 1991 and 1993 surveys and their implications for comparability of time-series data and longitudinal analysis.

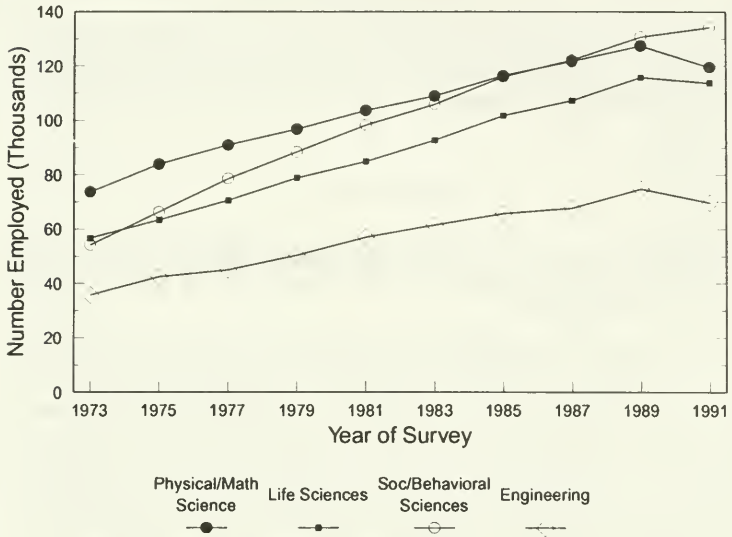

FIGURE 2-1 Growth in employment of doctoral scientists and engineers in the United States, 1973-1991.

SOURCE: NSF, 1991:Table 1, for 1973-1989; NSF, 1994d:Table 1, for 1991

NOTES: In this figure, postdoctoral appointees are included in the labor force.

The data are national estimates of the numbers of scientists and engineers with doctorates from US institutions. The estimates are derived from the biennial sample Survey of Doctorate Recipients conducted for the National Science Foundation by the Office of Scientific and Engineering Personnel, National Research Council.

In 1991, survey procedures and timing were changed in ways that improved the estimates but introduced major comparability problems. The response rate, which had fallen steadily during the 1980s (from 66% in 1979 to 58% in 1989), increased to 80% in 1991. Nonresponse bias in the earlier surveys had led to overestimates of 5% or more in the total number of scientists and engineers in the United States. The new procedures, which involved much more intensive followup of those who did not respond initially, no doubt reduced the overestimate, but the extent is not known. The drop in number of employed scientists and engineers from 1989 to 1991 is due at least in part to the change in survey procedures. For example, if the estimates in 1989 were reduced by 5%, the number of doctorates working in the United States would have increased by 3% instead of decreased by 3% from 1989 to 1991.

market either immediately or after a period of postdoctoral study.[2] Appendix C discusses employment trends among graduate scientists and engineers in more detail.

Although increasing numbers of new PhDs have been readily absorbed into the job market over the years, there are clear indications that the most recent new PhDs in some fields are not finding employment as easily as earlier ones, and graduates who have found employment have been more likely to find less-desirable or less-secure positions than earlier graduates.

Employment Trends

Among recent PhDs, there is a steady trend away from positions in education and basic research and toward applied research and development and more diverse, even nonresearch, employment.

Graduate scientists and engineers have traditionally been educated and prepared for employment positions in which the ability to perform original research is the skill of highest value. The traditional positions include research-intensive occupations in academe,[3] industry, and government laboratories where scholarship and research—especially basic research—constitute the primary focus of employment. During recent decades, such research-intensive jobs have increased steadily, and many new PhDs have been able to choose from an expanding number of such traditional jobs. However, available information on job distribution and trends in terms of both primary work activity and the location of that work indicates a persistent long-term trend away from employment in traditional research and teaching positions and toward applied research and development and non-academic employment (see Figure 2-2).

For example, the proportion of scientists and engineers engaged in basic research and teaching as their primary activity has declined while the proportion of people involved in applied research and development and other types of work has increased. According to the SDR, in 1973, 52% of scientists and engineers with PhDs from US universities were engaged in basic research or teaching activities, but, in 1991, only 37% were in such positions (Table C-3B). On the other hand, individuals employed in applied research and development increased by about one-third, and the fraction employed in business and industry increased from about 24% in 1973 to 36% in 1991. Within that group, the share of self-employed people more than quadrupled, to nearly 9% (Table C-3B).

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[2] An unknown number of graduate scientists and engineers graduating from foreign institutions also enter the labor market.

[3] Academe is defined in this report to include 4-year colleges, universities, and medical schools, but not 2-year colleges or precollege (K-12) educational institutions.

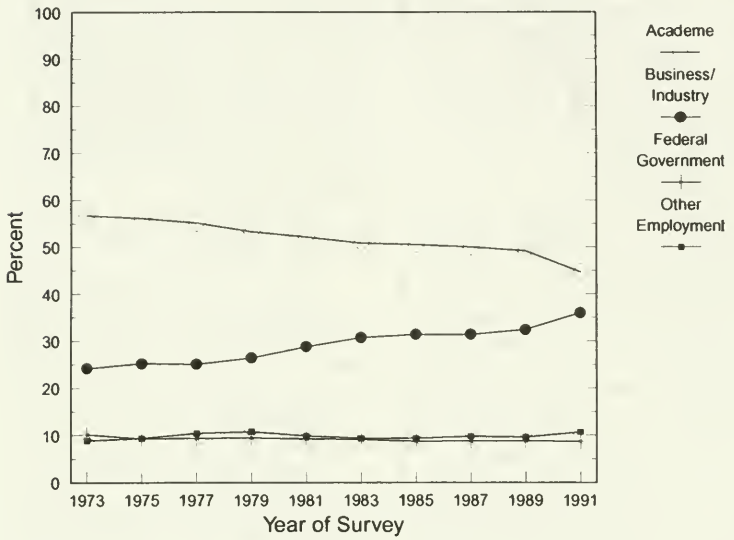

FIGURE 2-2 Scientists and engineers with US PhDs, by employment sector, 1973-1991.

SOURCE: Calculated from NSF, 1991:Table 3, for 1973-1989, and from NSF, 1994d:Table 9, for 1991.

NOTES: See notes for Figure 2-1 for important information about the comparability of 1991 estimates with the estimates for previous years.

Academe includes those employed at 4-year colleges, universities, and medical schools (including university-affiliated hospitals and medical centers).

Business/industry includes those who are self-employed.

Other employment includes other education (junior colleges, 2-year colleges, technical institutes, and elementary, middle, and secondary schools); state and local governments; hospitals and clinics; private foundations and other nonprofit organizations; other employers; and those who did not respond to the employment-sector question.

Furthermore, the fraction of total PhDs in science and engineering who are employed in academe has declined to less that half in recent years (see Figure 2-3). In addition, basic-research positions in some industry and national laboratories have also been declining. As a result, the activities and employment sectors that scientists and engineers with PhDs have been going into have been diversifying.

Those long-term trends are the basis for a major conclusion of this report, i.e., that **PhDs are increasingly finding employment outside universities and more and more are in types of positions that they had not expected to occupy.**

It should be noted that different fields and subfields of science and engineering vary widely with respect to employment patterns, job availability, and degree requirements. For example, in chemistry and engineering, many PhDs have long worked in industry; in other fields, many still work in universities.

Within nearly all fields, however, the broad trend is consistent: a smaller proportion of PhDs is going into universities and the federal government, and a larger proportion is going into business and industry (engineering was the only field in which the proportion of PhDs entering universities increased substantially. With the SDR data, it is possible to compare cohorts of scientists and engineers 5-8 years after receipt of PhD, i.e., after most of them have completed a period of postdoctoral study. More than half the 1969-1972 science and engineering PhDs were employed in universities in 1977, compared with less than 43% of the 1983-1986 PhDs in 1991 (Figure 2-4). Only 26% of them were employed in business and industry in 1973, compared with 35% in 1991.

Employment difficulties are most acute among new PhDs, many of whom are unable to find desirable positions in their field. Barry Hardy, who has done postdoctoral work at the National Institutes of Health and is currently a postdoc at the University of Oxford in England, has spoken out about these difficulties and offered suggestions for change. With several other members of the Young Scientists' Network Internet discussion forum, he wrote an open letter to Harold Varmus, director of the National Institutes of Health, outlining options for change.

At the committee's invitation, Dr. Hardy offered a series of suggestions for improving the graduate education experience:

- Include young scientists and engineers on policy panels, especially those affecting the funding of graduate students.
- Improve the evaluation of training grant programs.
- Fund an Internet-based information gathering and sharing system.
- Modify graduate student programs so they are more flexible and diverse.
- Improve employment conditions for postdocs so they can support their families and expect reasonable job security.
- Increase participation of young scientists at conferences.
- Reduce constraints on expression by graduate students.
- Balance immigration policies and fair treatment of foreign students.
- Develop computer simulation models to better predict science and technology employment patterns.

Box 2-1: The plight of the new PhD - Suggestions for change

Appendix C provides an in-depth analysis of the employment distribution of new and recent science and engineering PhDs by discipline. This is an original analysis based on data from the SDR. Information on a sectoral basis is also provided in the next section of this chapter.

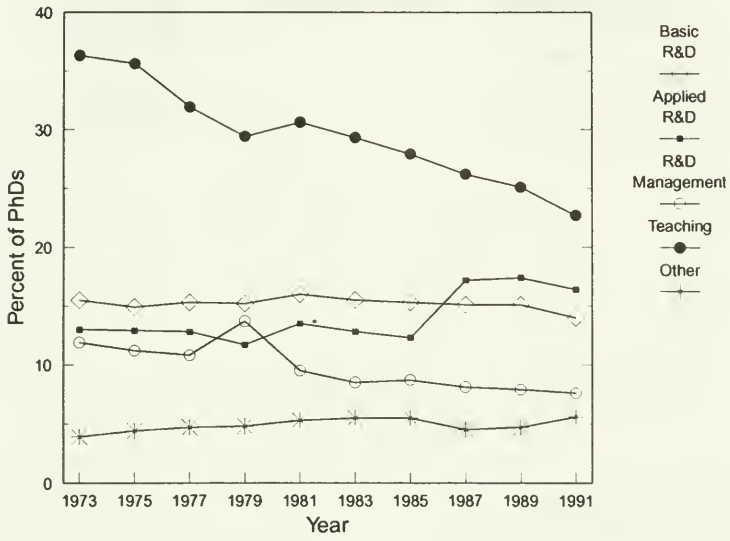

FIGURE 2-3 Primary work activity of scientists and engineers with PhDs from US universities, 1973-1991.

SOURCE: Calculated from NSF, 1991:Table 3, for 1973-1989 and from NSF, 1994d:Table 10, for 1991.

NOTES: See notes for Figure 2-1 for important information about the comparability of 1991 estimates with the estimates for previous years.

The other activities surveyed, which accounted for nearly 20% of the PhD scientists and engineers in 1973, increasing to almost one-third in 1991, included management of non-R&D activities, consulting, professional services, statistical/data analysis/reporting, and "other" and "no report."

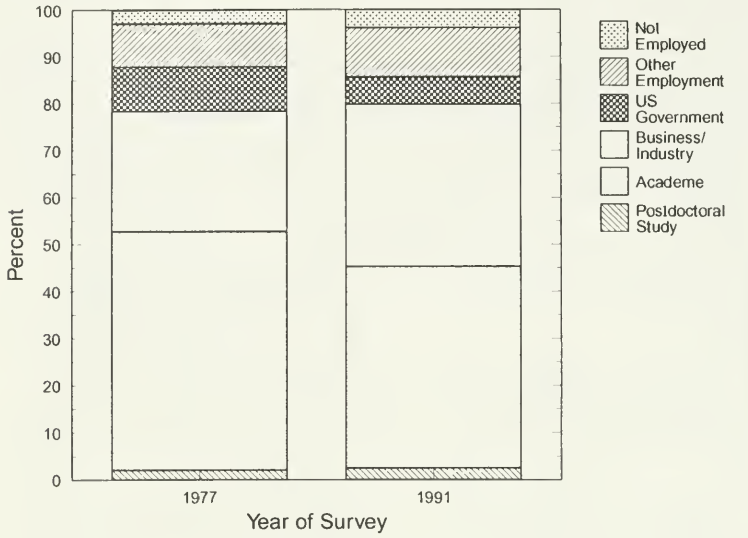

FIGURE 2-4 Change in employment sector of scientists and engineers 5-8 years after receipt of US doctorates, 1977 and 1991

SOURCE: Special runs of data from the Survey of Doctorate Recipients on employment sector of US doctoral scientists and engineers 5-8 years after receiving the PhD (in this case, 1969-1972 PhD recipients in 1977 and 1983-1986 PhD recipients in 1991). Psychology PhDs, many of whom go into clinical psychology, are not included in the totals.

NOTES: See notes for Figure 2-1 for important information about the comparability of 1991 estimates with the estimates for previous years.

Academe includes those employed at 4-year colleges, universities, and medical schools (including university-affiliated hospitals and medical centers).

Business/industry includes those who are self-employed.

Other employment includes other education (junior colleges, 2-year colleges, technical institutes, and elementary, middle, and secondary schools); state and local governments; hospitals and clinics; private foundations and other nonprofit organizations; other employers, and those who did not respond to the employment-sector question.

Not employed includes the unemployed (seeking work) and those not seeking employment, retired, or otherwise out of the workforce or not reporting workforce status.

Unemployment and Delayed Employment

Recent graduate scientists and engineers have been experiencing increasing delays in securing permanent employment.

The employment picture for scientists and engineers, especially for recent graduates, is not clear, partly because the pertinent national surveys of new and recent PhD recipients lag by several years. The picture is complicated by wide differences among fields, some of which are shrinking as others grow. Nonetheless, we find clear evidence of employment difficulties in many disciplines.

Such difficulties are hard to detect with traditional measures, such as the SDR. According to SDR data, unemployment rates for PhD scientists and engineers have remained steady and low for the last decade, compared with those in other segments of the economy. Unemployment rates for PhD scientists and engineers were about 1% in the 1980s surveys and about 1.5% in the 1990s. Unemployment rates for the most recent 2 years of science and engineering PhD graduates were about 1.5% in the 1980s, but rose to 2% in 1993, the last year for which data are available—a disquieting increase that bears watching.[4] The latter rate compares favorably not only with the overall unemployment rate (above 6% in the early 1990s), but also with unemployment among professional occupations generally (2.6% in 1992 and 1993) and among those with at least a college degree (around 3% in the early 1990s) (see Figure 2-5).

The evidence obtained through committee panels and submitted comments (see Appendix G) and through surveys of recent PhDs by some of the scientific societies shows that an unusually high percentage of scientists and engineers are still looking for employment at the time of or soon after receiving their doctorates. Results of surveys by the professional societies of physicists, chemists, and mathematicians indicate that graduates in some fields are experiencing double-digit unemployment for increasing periods after graduation. **Recent scientific and engineering PhDs do eventually find employment, but in some fields the process is taking much longer than it did for their predecessors.**

For example, the mathematical societies conduct surveys of new PhDs each summer and update them in the spring. The percentage of new PhD mathematicians still looking for positions in the summer was about 5% during most of the 1980s but in 1990 began to rise to more than 12% for the classes of 1991-1993.[5] According to the American Mathematical Society (AMS) the percentage of new mathematicians looking for employment the summer after receiving their PhDs was 14.4% for the class of 1994, even though the number of new PhDs was 12% smaller than the class of 1993 (AMS, 1994b). Similarly, the percentage of new PhDs still unemployed in the next spring was about 3% in the late 1980s, 5% for the class of 1991, 7% for the class of 1992, and 9% for the class of 1993 (AMS, 1994a). The American Institute

[4] It is not known how much of this increase in unemployment rates should be attributed to a change in survey methods.

[5] A class is defined as those graduating each year from June to June.

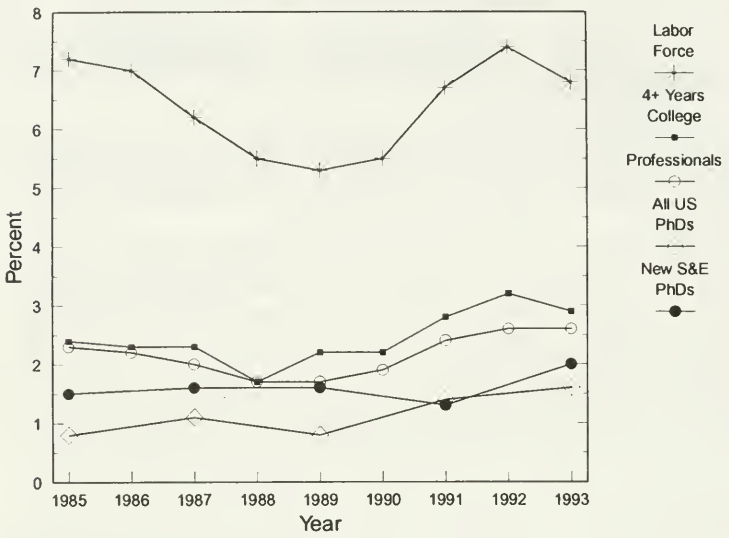

FIGURE 2-5 Unemployment rates among different occupational and educational groups in the civilian noninstitutional labor force, 1985-1993.

SOURCES: US Bureau of the Census, 1994:Table 616, for average monthly unemployment of the civilian noninstitutional labor force aged 16 or older.

US Bureau of the Census, 1994:Table 650, for average monthly unemployment of the civilian noninstitutional labor force aged 25 or older with 4 years or more of college.

US Bureau of the Census, 1994:Table 649, and unpublished Bureau of the Census tables, for average monthly unemployment among civilian noninstitutional labor force aged 16 or older in professional specialty occupations (includes S&Es).

NSF, 1991, NSF, 1994d, and unpublished SDR tables, for unemployment among S&Es with doctorates from US universities.

Unpublished SDR tables, for unemployment among S&Es 1-2 years after receiving PhD from US university.

of Physics (AIP), which also surveys new PhDs each year, found that in 1993, 14% of new doctoral physicists looking for employment had not received a job offer around the time of graduation, a figure that dropped to 6% six months after graduation. Preliminary estimates for the class of 1994 indicate that those numbers were about 12% and 4% respectively (unpublished AIP data). An American Chemical Society survey of new chemists found that more than 16% of the PhD class of 1993 were seeking employment during the summer of 1993 (Table B-1a in ACS, 1993).

Underemployment and Underutilization

When recent graduates do find employment, they are increasingly underemployed or underutilized.

Doctoral students trained in American universities are traditionally well educated for permanent or tenure-track positions in which they conduct significant research in universities, industry, or government agencies. In the recent past, the US science and technology enterprise has grown so rapidly that most advanced-degree holders could expect such a position after graduation. Testimony provided to the committee, however, indicates that today many more new science and engineering PhDs are able to obtain only part-time positions, short-term non-tenure-track positions, postdoctoral positions that are extended for nonacademic reasons, or positions that are not of the expected type and for which one does not explicitly require a PhD degree.[6]

The National Science Foundation (NSF) uses two technical categories to describe such conditions. The **underemployed** are defined as those working part-time but seeking full-time work or those working in a nonscience and nonengineering job but desiring a science or engineering job. The **underutilized** are the **unemployed** (those who do not have positions but are seeking positions) **plus the underemployed** (NSF, 1994d:69). When considering the employment trends that graduate scientists and engineers have generally had since World War II, underutilized recent PhDs might be described as scientists and engineers whose present employment positions have not matched their career expectations.

The SDR includes both underemployment and underutilization rates. In 1991, for example, 89.7% of scientific and engineering PhDs were employed and 1.4% were unemployed (together, these are considered the total scientific and engineering labor force).[7] Of those employed, 1.7% were underemployed as defined above. Therefore, of the total labor force, 3.1% were underutilized. The underemployment rate was 1.3% in 1985, 1987, and 1989 and

[6] Data limitations prevent quantitative analysis and verification of some of these claims.

[7] The remaining 8.9% were retired, not looking for work, or otherwise out of the workforce. It is important to note that the survey retains people in the sample for 42 years, so some people are past common retirement ages.

1.7% in 1991.[8] The underutilization rate was 2.1% in 1985, 2.4% in 1987, 2.1% in 1989, and 3.1% in 1991. Those figures, of course, differ by field.

Anecdotal information also indicates that although recent scientific and engineering PhDs are seldom working in jobs for which their graduate work is not relevant (e.g., working in a restaurant), they are increasingly able to obtain only part-time or temporary positions. Data collected by the scientific societies are also useful. For example, results of the AMS survey cited earlier indicate that beyond the 9% unemployment rate, an additional 5.5% of recent PhDs were able to obtain only part-time positions, and more than half those taking faculty jobs were in non-tenure-track positions (AMS, 1994a). About 10% of the physics PhD class of 1992 was working in temporary or part-time positions (Kirby and Czujko, 1993:23).

Another statistical indicator of underutilization is the rising percentage of new PhDs taking postdoctoral positions. A postdoctoral position is intended to provide further depth of education and job preparation, but it can also act as a safety net when the labor market is poor. The number of scientists and engineers in postdoctoral positions has grown substantially, from less than 15,000 in 1982 to more than 24,000 in 1992 (see Table B-38). From 1991 to 1992, the number increased by 5%.

Surveys do not determine the extent to which young scientists and engineers take postdoctoral positions for lack of regular employment. In chemistry, for example, the pool of postdoctoral scientists and engineers is estimated to have doubled during the last 10 years to more than 4,000. This is equivalent to the number of chemists who receive PhDs in 2 years (Rawls, 1994). Some attribute at least part of this increase to the preference of employers—especially pharmaceutical companies—for chemists with 3 or 4 years of postdoctoral experience.

2.2 EMPLOYMENT TRENDS BY SECTOR

Most of the long-term growth in employment demand for graduate scientists and engineers has occurred in business and industry.

Professional careers are becoming increasingly varied and nonacademic, although this varies somewhat by discipline (see Figure 2-6). More and more scientists and engineers are being exposed to nonacademic fields before, during, or after their academic preparation. In

[8] As this report was going to press, NSF released a *Data Brief* citing 4.3 percent underemployment among doctoral scientists and engineers in 1993. This rate should not be compared with the reported 1991 rate of 1.7 percent, however, because the definition of underemployment was broadened between the 2 survey years. In 1991, individuals were counted as underemployed if they were working part-time or outside of science or engineering when they desired a science or engineering position. In 1993, the requirement was expanded to include those working part-time or outside their doctoral field when they desired a position within their doctoral field.

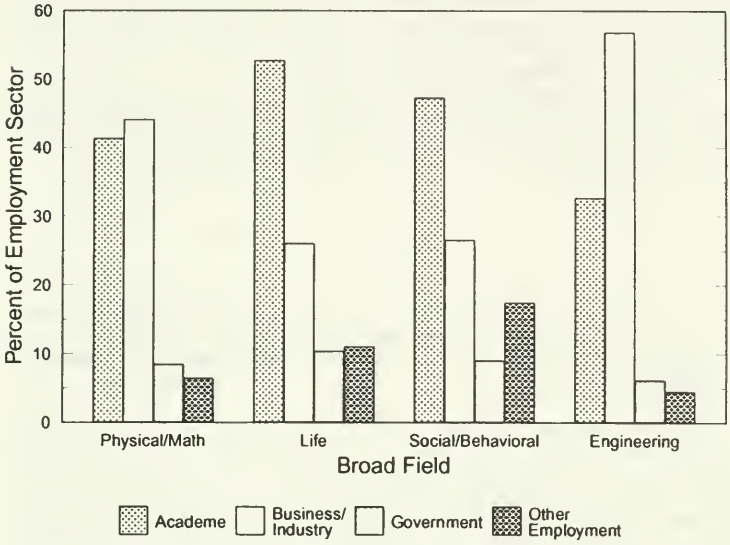

FIGURE 2-6 Employment sectors of scientists and engineers with US PhDs, by broad field, 1991.

SOURCE: Calculated from NSF, 1994d:Table 9.

NOTES: *Academe* includes those employed at 4-year colleges, universities, and medical schools (including university-affiliated hospitals and medical centers).

Business/industry includes those who are self-employed.

Other employment includes other education (junior colleges, 2-year colleges, technical institutes, and elementary, middle, and secondary schools); state and local governments; hospitals and clinics; private foundations and other nonprofit organizations; other employers; and those who did not respond to the employment-sector question.

addition, because more courses are offered as evening or "distance learning" programs, many graduate students work part- or full-time as they study.

Although most graduate scientists and engineers remain in the same general field as that of their bachelor's degree, many switch fields and thereby obtain interdisciplinary training. Furthermore, throughout their careers, graduate scientists and engineers commonly change subjects, kinds of employment, and employment sectors, moving, for example, between educational, industrial, business, and government organizations.

The following sections attempt to describe the direction of employment trends by sector. Although not included in the following section because of the lack of information on their activities, an additional 29,000 PhDs work in nonprofit institutions—including 9,000 in research and development, 9,500 in professional services, and 6,000 in administration (NSF, 1991).

Education

Of students who earn science and engineering PhDs, the proportion who enter academe has declined to less than half, and this long-term decline is likely to continue. However, there is likely to be increasing demand for teachers in precollege positions.

In the educational sector, according to the 1989 SDR, 48% of the 22,000 people working in universities said their primary activity was teaching and 36% said research and development (24% basic research, 12% applied research and development). Of the 10,000 employed in other educational institutions (precollege and community college), 59% were teachers and 15% were administrators (calculated from Table 27 in NSF, 1991). In 1992, of the 176,777 faculty and staff (regardless of degree) with instructional responsibilities in natural sciences[9] and engineering in postsecondary institutions,[10] 71% were full-time and 29% were part-time (NCES, 1994).

As shown in Table 2-1, between 1977 and 1991, the proportion of scientists and engineers with US doctorates who were employed in colleges and universities declined from 51% to 43%.[11] This trend was true for all fields except mathematics (which had a 1-year rise in 1991 after years of decline) and engineering. Only 31% of those who received PhDs in 1983-1986 were in tenure-track positions or had tenure as of 1991, whereas more than 35% of those who received PhDs in 1973-1976 were in such positions or had tenure in 1981.

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[9] "Natural sciences" are defined by the US Department of Education to include biological sciences, physical sciences, mathematics, and computer sciences.

[10] "Postsecondary institutions" include junior colleges, 4-year colleges, and universities.

[11] Note that some of this change might be due to an overestimation of the numbers of persons employed in academe in earlier surveys. This analysis was done for persons 5-8 years after they received their PhDs to account for the time taken in postdoctoral study, which varies by field.

TABLE 2-1 **Changes in Percentages of Scientists and Engineers Employed in Academe 5-8 Years after Receiving US PhD, by Broad Field, 1977 and 1991**

	1977	1991
TOTAL	50.7	42.9%
PHYSICAL SCIENCES	46.5	37.3
Mathematical sciences	74.4	76.0
Computer sciences	45.8	41.8
Physics/Astronomy	45.9	38.3
Chemistry	32.1	21.2
Earth/Environmental sciences	50.2	45.1
LIFE SCIENCES	58.2	46.5
Agricultural sciences	55.4	47.1
Medical sciences	56.5	50.7
Biological sciences	59.1	45.7
SOCIAL SCIENCES	74.4	55.4
Psychology	45.7	26.0
ENGINEERING	28.8	32.2

NOTES: See notes for Figure 2-1 for important information about the comparability of 1991 estimates with the estimates for previous years.

Academe includes those employed at 4-year colleges, universities, and medical schools (including university-affiliated hospitals and medical centers).

SOURCE: Special runs of data from the Survey of Doctorate Recipients of employment sector of US doctoral scientists and engineers 5-8 years after receiving the PhD (in this case, 1969-1972 PhD recipients in 1977 and 1983-1986 PhD recipients in 1991). Psychology PhDs, many of whom go into clinical psychology, are not included in the totals.

Consider, however, our precollege-education system as an alternative employment market. Employment of master's-degree recipients and PhDs at the precollege level is expected to grow, and the salaries of entry-level teachers at the PhD level in many precollege school systems are not strikingly different from those of entry-level professors. According to Department of Education projections for the year 2002, the total number of science-related pre-college teachers is about 480,000 and is expected to increase by 1.3-1.6% per year, which would create thousands of new positions annually (plus those created by retirement or attrition). The average entry-level salary of a precollege teacher with a PhD is about $35,800, and that of an entry-level professor is about $36,600 (NCES, 1991;1993).

Some might question whether this is an appropriate occupation for someone with a PhD science or engineering education. However, it is generally agreed that a basic education in science and mathematics will be essential to prepare all Americans for effective participation in our increasingly scientific and technical society in the 21st century. The national science-education standards prepared by the National Research Council call for hands-on inquiry-based science to become a core subject for all Americans starting in kindergarten (NRC, 1995 forthcoming). Who will lead this effort in each of the 16,000 school districts in the United States? And who will teach our children inquiry-based science? Large numbers of scientifically trained teachers are needed if science and mathematics

Gerald Stancil received his PhD in physical chemistry from Johns Hopkins University in 1976. Today he is a high-school physics teacher in Orange, New Jersey. Is he disappointed? No, because when Dr. Stancil came to Orange High School, there was one physics class with 13 students. Today, there are three physics classes with 75 students.

He is doing what he wants to do. But he was not guided to this path in graduate school, where he learned that PhDs do not work in public schools. Nor was he schooled in the skills and abilities he uses most today—communication skills and social skills—or in an understanding of youth or a love of sharing his knowledge with others.

Dr. Stancil entered the high-school classroom 4 years ago through a New Jersey program called Alternate Route, set up specifically to attract people with graduate degrees to public-school teaching. In his comments to the committee, he noted that such alternative-teaching certification programs are becoming more common. In the past, many educators opposed hiring people at the graduate level; today, they recognize the growing need for better-prepared teachers in science and engineering.

In the New Jersey program, a 1-year course leads to provisional certification. Then the new teacher works with a mentor and after 2 years receives full certification. Other states, including Maryland, New York, and Pennsylvania, have initiated similar programs.

Dr. Stancil believes that PhDs can make a great contribution to precollege education. He told the committee that many public-school students don't even know what a PhD is; for example, they ask him for medical advice. He believes that because of such ignorance, many potential scientists and engineers are lost at around the eighth grade. As a black man, he is able to serve as a model for minority-group students, who might have little understanding of how to approach a career in science and engineering.

He does not have to make a financial sacrifice to do what he is doing. He told the committee that people with PhDs teaching high school make salaries comparable with the median salaries at most universities. Starting teachers with PhDs make about $36,000 in New Jersey, and senior PhD teachers like him earn a salary of about $55,000 for 9 months of work a year.

Box 2-2: A High-School Teacher with a PhD

are to be core subjects for all precollege students; however, current graduate-education programs do not provide sufficient knowledge, validation, or training regarding education for graduate scientists and engineers to make a transition from scientific and engineering research to teaching at these lower levels.

Some states offer innovative certification programs in precollege teaching for those with advanced degrees (see Box 2-2). As indicated by one committee witness, such programs can enliven precollege education and offer unique rewards to teachers. Furthermore, the talent of motivated graduate scientists and engineers should raise the overall level of science education for younger students who might eventually enter science and engineering.

Government

Positions for graduate scientists and engineers in government are decreasing, and this trend is likely to continue. However, there is likely to be more demand for scientists and engineers to work in particular fields, such as those related to environmental protection.

In the government sector, of the 29,000 PhDs working for the federal government in 1989, half were in research and development and one-fourth were administrators. Of the 16,000 in research and development, one-third were in basic research and more than half in applied research. In the case of the 11,000 PhDs working in state government, about one-fifth were in research and development and one-third were in management (calculated from NSF, 1991).

The federal government has long been a major source of employment for scientists and engineers. However, as shown in Table 2-2, this trend is decreasing for all fields except earth/environmental sciences. As of September 1993, 112,543 engineers and 99,239 scientists were federal employees.[12] Of the engineers, 3,681 had doctorates and 25,482 had master's degrees; of the scientists, 18,109 had doctorates and 25,744 had master's degrees.

In 1989, the federal government hired more than 13,000 new scientists and engineers—1,100 with PhDs, 2,600 with master's degrees, and more than 9,000 with other degrees.

By 1993, low turnover, program cuts, and hiring freezes had reduced the number of newly hired scientists and engineers to barely 4,000, or about 71% fewer than in 1989 (81% fewer engineers, because of staff reduction in the Department of Defense, and 50% fewer scientists). Moreover, those being hired were a little older, probably because the federal agencies had a choice of people with more experience.

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[12] Data on federal employment of scientists and engineers were provided by Leonard Klein, Associate Director of the Office of Personnel Management, Career Entry and Employee Development Group, in a presentation to the Committee on Science, Engineering, and Public Policy at its April 6-7, 1994 meeting at the National Academy of Sciences in Washington, D.C.

TABLE 2-2 **Changes in Percentages of Scientists and Engineers Who Are Civilian Employees of the Federal Government 5-8 Years after Receiving US PhD, by Broad Field, 1977 and 1991**

	1977	1991
TOTAL	9.5	5.9
PHYSICAL SCIENCES	9.1	5.5
Mathematical sciences	3.5	1.9
Computer sciences	9.5	0.8
Physics/Astronomy	13	9.5
Chemistry	6	2.4
Earth/Environmental sciences	18.0	22.7
LIFE SCIENCES	9.7	6.7
Agricultural sciences	16.1	11.7
Medical sciences	7.8	5.7
Biological sciences	8.3	5.7
SOCIAL SCIENCES	5.8	5.1
Psychology	3.8	2.4
ENGINEERING	12.9	5.4

NOTES: See notes for Figure 2-1 for important information about the comparability of 1991 estimates with the estimates for previous years.

SOURCE: Special runs of data from the Survey of Doctorate Recipients of employment sector of US doctoral scientists and engineers 5-8 years after receiving the PhD (in this case, 1969-1972 PhD recipients in 1977 and 1983-1986 PhD recipients in 1991). Psychology PhDs, many of whom go into clinical psychology, are not included in the totals.

There are niches of opportunity in specific fields, such as energy and environment, but the overall numbers are steady or declining because of staff reductions and low turnover.

Business and Industry

Over the long term, demand for graduate scientists and engineers in business and industry is increasing; more employment options are available to graduate scientists and engineers who have multiple disciplines, minor degrees, personal communication skills, and entrepreneurial initiative.

In the business and industry sector, according to the 1989 SDR, of the 113,000 working in for-profit organizations, half listed research and development as their primary activity. Most—35,000—were in applied research, and another 18,000 did development work. Another large group—29,000—were administrators and managers (primarily of research and development). Less than 3% of the PhDs in industry were doing basic research. Of the 32,000 who were self-employed, half were in professional services and one-fourth were consultants (calculated from NSF, 1991).

As shown in Table 2-3, the proportion of scientists and engineers employed in business and industry for all fields has increased from 26% in 1977 to 35% in 1991. In some fields—such as chemistry, engineering, and computer science—graduate scientists and engineers have long found employment in nonacademic markets. But survey data, buttressed by testimony of committee witnesses and correspondents, show that this trend now applies to

Some PhDs are now adapting to fields once considered remote from science and engineering. Albert Bellino, an executive at Banker's Trust in New York, told the committee that investment banking is one such field in which advanced scientists and engineers are held in high esteem.

Mr. Bellino is a managing director at Banker's Trust, one of a number Wall Street firms that hire a total of perhaps 100 PhDs in science each year. His firm, for example, hires about 10-15 PhDs each year. In total, the company now employs approximately 150 PhDs among its 5,000 employees. Most newly hired employees have traditionally been economists, but the number of PhDs in physical sciences and mathematics is rising. The company believes that such training is excellent preparation that is easily transferred to financial markets.

There have been other changes in the qualities desired at Banker's Trust. In the past, said Mr. Bellino, the bank looked for these traits: "hardworking, reliable, local, team player, consistent performer." Now, it prefers "smart, intense, driven, problem solver, entrepreneur, quixotic, a little abrasive." It used to seek out people who were involved in jogging, swimming, tennis, and travel; now, it looks for bridge, chess, crossword puzzles, trading of baseball cards or stamps, linguistics, and music.

Mr. Bellino explained that the latter traits are desirable because investment banking has become an "ideas business." It wants people who have the best ideas, who know how to implement ideas, and who can manage risk on behalf of their clients and themselves. It also seeks those with an interest in markets (for example, someone who ran a family fund or had such a hobby as trading baseball cards) and those whose communication skills enable them to be effective in a less-hierarchical organization.

Box 2-3: Investment Banking

TABLE 2-3 **Changes in Percentages of Scientists and Engineers Employed in Business/Industry 5-8 Years after Receiving US PhD, by Broad Field, 1977 and 1991**

	1977	1991
TOTAL	25.6	34.5
PHYSICAL SCIENCES	30.4	44.2
Mathematical sciences	12.2	18.6
Computer sciences	42.0	50.3
Physics/Astronomy	25.1	38.2
Chemistry	45.5	60.9
Earth/Environmental sciences	18.6	22.7
LIFE SCIENCES	12.9	26.4
Agricultural sciences	17.9	30.8
Medical sciences	15.9	26.4
Biological sciences	11.4	25.4
SOCIAL SCIENCES	5.6	13.1
Psychology	15.4	36.5
ENGINEERING	50.5	56.7

NOTES: See notes for Figure 2-1 for important information about the comparability of 1991 estimates with the estimates for previous years.

SOURCE: Special runs of data from the Survey of Doctorate Recipients of employment sector of US doctoral scientists and engineers 5-8 years after receiving the PhD (in this case, 1969-1972 PhD recipients in 1977 and 1983-1986 PhD recipients in 1991). Psychology PhDs, many of whom go into clinical psychology, are not included in the totals.

other fields as well (see Table 2-1). For example, in biological sciences, the percentage employed in business and industry increased from 11% in 1977 to 25% in 1991.

The evidence received by the committee indicates that the trend will continue and that most job creation for scientists and engineers in coming years will occur in business and industry. However, for a variety of reasons, some large industries are modifying or closing their central research laboratories: some have become smaller, and some have shifted into enterprises that emphasize development, marketing, and R&D activities that are designed primarily for short-term economic gain. Hence, although industries will continue to perform research and to offer employment, they might not support traditional research to the degree that they have in the past.

In small and medium-size companies, new and emerging technologies develop rapidly. Such companies provide one of the few increases in R&D funding. Because staff sizes in such companies are limited, successful science and engineering employees are those who can cross disciplinary boundaries and have talents in product development, manufacturing, or technical services.

Jobs in industries that depend on emerging technologies show steady increases (which, however, can fluctuate with the business cycle). Within those industries are fields that are expanding, such as manufacturing simulation, information science, computational simulation, software engineering, data processing, visualization, forensic science, and electronic networking.

2.3 EMPLOYER PERSPECTIVES

As part of its outreach effort, the committee sent out a call for comments to over 1,000 persons: graduate students, postdoctoral researchers, professors, university administrators, industry scientists and executives, and representatives of scientific societies. The 100 responses received (50% of which came from industry) are summarized in Appendix F. This section provides an overview of graduate education from an employer perspective.

Why do organizations employ individuals with a scientific background? Here is a view from the president of a biotechnology company:

> We employ people with a scientific background in almost all aspects of our operations: general management, marketing and sales, business development, regulatory and quality affairs, clinical development, manufacturing and, obviously, research and research management. We find that a scientific education prepares people well for a number of careers, because it teaches them to be analytical, adaptable, and pragmatic problem-solvers. Furthermore, the spirit of scientific enterprise encourages them to be entrepreneurial which is an increasingly valuable personal quality across the breadth of today's commercial environment.

What do employers think of the current science and engineering graduate education program? Generally, industry and academic administrators responded favorably to the current concept of graduate education, although they expressed some concern as to the relationship between that education and the positions eventually attained. The following statement typifies the general sentiment: "We may see some specific difficulties in the relationship between academe and the profession it is intended to serve, but the structure itself is sound."

Some concerns were also expressed about the level of additional education that is needed to enable recent graduates to become fully participating employees. Consider the response from one major industrial employer who hires several hundred people with graduate science and engineering degrees in laboratories each year from many universities and in many disciplines:

> Even "the best of the crop" take anywhere from 6 months to 2 years to become good, productive industrial researchers. Most recent graduates, particularly those who have not summer-interned, do not have the foggiest idea of what industrial research is all about. Some even think that using or developing technology to do something useful is not research and if it is a product that makes a profit, is even slightly dishonorable.

Those from the academic arena had concerns as well—focused primarily on the teaching and mentoring skills of students trained in the science and engineering graduate system. The following comment is from a graduate dean and provost:

> I have long been concerned about the teaching expectations of graduate students—all graduate students, not just in the sciences and engineering. How we can expect that an individual will intuit teaching skills is an amazement. While teaching is somewhat an art, there are many skills and techniques that need to be learned before an individual should be turned loose to teach a course. We do our graduate students no service, and certainly provide no service to the teachers, if we expect them to function in that capacity....They also need to be prepared to be academic advisers. It is not enough to walk into a class and conduct that experience. If graduate students are to be teachers, they need to know how to interact outside the classroom with undergraduate students, providing them the support that they should have during their undergraduate experience.

A common subject was the changing environment—in both the industrial and the academic world. The following is from the dean of a major graduate school:

> Graduates are not necessarily being well trained to participate in much of our higher educational system as faculty: facilities for front-line research in sciences are not likely to get less costly. Not many colleges and universities will be able to afford the kinds of equipment required for faculty to make significant contributions to science in many areas. If this is true, most academic PhD positions will be in institutions which do not have essential facilities for what is viewed by these fields as cutting-edge research. Either the faculty in such institutions will have to carve out areas of research which don't rely on expensive equipment, or they will have to change their expectations of being significant players on the national and international science scene. It may be that there should be some effort devoted to training PhDs for research appropriate to those other institutions, either for enhancing their instructional roles or for providing them with realistic lines of research.

These are from an industry perspective:

> In my judgment, educating and training students to do research as well as conducting basic research are still the primary objectives of graduate programs. However, [the programs] must be responsive to changing national policies and industrial needs.... I would agree that the American graduate system has been/is a great success. However, to ignore the indicators that show change is needed would be a mistake. Clearly, the challenge ahead is to retain the best of the system while making the changes that will strengthen the nation's outstanding research universities and make them more responsive to the nation's needs.

* * * * * * *

> The days when a person could do a PhD thesis in surface thermodynamics (as I did) and reasonably expect to work in the field for a career are over—and I think will never return. One must be ready with the skills to change one's area of focus several times over a career. Most PhD education is training people in the exact opposite direction, and I think this needs to be changed promptly.

This comment from a university graduate dean shows both perspectives:

> Unfortunately, the training the graduates receive in universities is not directed to any specific career path. Most of the time, after some necessary training in their background, graduate students are pushed into narrow specialization. The consequence of such training is that many of them lack the breadth for work in industry. From what I have seen from the job offers received by our engineering students, they are successful with relatively less effort if their research topic and/or their assistantship experience is closely related to the prospective job description.
>
> The universities are not doing any better in training PhDs for academe either. Except for the recent initiatives taken by some universities in giving them pointers on effective teaching, generally their training is in a narrow area of research and they are faced with on-the-job training.

There was also a general concern that although the scientific and technological education received was sufficient, the skills training that is part of that educational experience was not. The following comment is from a major consulting firm:

> It is our general finding that US graduate schools successfully continue their tradition of producing well-educated scientists and engineers that are capable of making important contributions in their chosen fields. We also believe that the effectiveness of these graduates could be enhanced through practical ("hands-on") experiences/traineeships, functioning as a member of a (multidisciplinary) team, strengthened interpersonal skills, ability to communicate clearly the purpose (including the "strategic" value and relevance) of the activity in question, and substantial knowledge of the business environment/culture (including project-management fundamentals, time/effort/budget deliverables, sensitivity to human-resource concerns, safety, intellectual property, etc.).

These are from international corporations:

> Why are industries such as ours not more accepting of PhDs with little or no experience? Because many fresh PhDs see their research area as their sole focus, at least for the immediate future. They generally tend to be very narrow. And, more important, they generally have no meaningful understanding of the *business* of business. Some might say that such understanding is the responsibility of

business to provide. I say no. A highly trained scientist or engineer cannot be very effective if she/he has no knowledge at all of how a company is organized and why, lacks understanding about the principal staff and operating functions, is ignorant of the rudiments of accounting and finance, is unaware of product-liability issues that directly affect product development, etc., etc. Industry cannot be expected to deliver such training and education in a short period of time. True, with years of experience working in industry such knowledge is slowly acquired—but it is an extremely inefficient transfer mechanism. Meanwhile, in the early years when the new technologist is working without awareness of these forces and boundary conditions, that person cannot be as effective as she/he otherwise might be. Careers are throttled.

* * * * * * *

Most of the new PhDs that we hire seem to be relatively well prepared for careers in our organization. I would urge, however, that rather than move towards increasing specialization, which occurs very early in their training, the students should be given a broad array of courses in related areas early in their training. I have the impression that, also from day one in their program, students are now put into laboratories and given a research project so that they can develop the knowledge and skills in their specific area of activity to allow them to compete for grants in the future. However, it has been my observation that this type of training limits their ability to participate in multi-disciplinary teams that are often necessary in the industrial setting.

* * * * * * *

We look for top-notch technical skills and some evidence of ability to "reduce to practice" the technologies the candidate has been involved in. If we look at new graduates, we look for curiosity about and an appreciation for practical applications of science. As we move away from independent, stand-alone research and toward more team projects, we screen and hire candidates based on their ability to work in teams, to lead collaborations and teams in an effective way. Skills like project management, leadership, planning and organizing, interpersonal skills, adaptability, negotiation, written and oral communication and solid computer knowledge/utilization are critical for an industrial R&D scientist/engineer. If you walk on water technically but can't or won't explain or promote your ideas and your science, you won't get hired. If you do get hired, your career will stall.

Expectations are slightly different for those with master's degrees and PhDs. Here is an overview from a major company:

> In the case of PhDs we are looking for high intelligence and creativity, the ability to originate and conduct independent research, a research background involving at least a solid thesis research experience, and the potential breadth of talent to move from one research field to another. The flexibility required by the latter point is important to us because we cannot hire new talent every time we wish to enter new research fields.
>
> We are also looking for excellent communication and interpersonal skills, so that with proper training they can develop into potential management candidates both in the research organization and in management positions in our operations. We have had a good track record in our research organization in supplying high-caliber talent to our operations.
>
> In the case of master's-degree candidates, we are looking for the same kind of talents, except we do not expect experience in conducting research.

A number of universities are attempting to improve the preparation of graduate students who plan to become professors. One example is a pilot program at North Carolina State University, "Preparing the Professoriate." N.C. State found in focus-group discussions that doctoral students wanted "opportunities to prepare more fully for the academic life of a professor...to learn to teach in the same way that they learn to do research in a significant and extensive advising atmosphere."

The program uses "mentoring pairs," each of which teams a doctoral candidate with a current or emeritus professor. Throughout an academic year, the mentors work with their graduate students ("teaching associates") to develop individualized plans for substantive teaching experiences: these range from course preparation and planning to final course evaluation.

Students document their experience by developing a professional portfolio, which can include student evaluations, letters of recommendation that specifically address teaching, and evidence of course planning and preparation with videotapes. The portfolio may be used when a student applies for a position in academe.

Box 2-4: Preparing Professors

In summary, the anecdotal information collected via the committee's call for comments indicates that although employers are generally pleased with the result of US graduate education, they have some specific concerns as to its breadth, versatility, and skill development. In particular, employers do not feel that the current level of education is sufficient in providing skills and abilities to the people that they are interested in employing, particularly in

- Communication skills (including teaching and mentoring abilities for academic positions).
- Appreciation for applied problems (particularly in an industrial setting).
- Teamwork (especially in interdisciplinary settings).

They are also concerned that the graduate-education system—although acceptable for the past employment world—is less and less acceptable in today's more global world.

2.4 THE CHANGING CONTEXT OF EMPLOYMENT

During the preparation of this report, the committee heard sufficient testimony to be convinced of the considerable pain and dislocation among new PhDs. One forum for such discussions is the Young Scientists' Network (YSN), through which junior scientists and engineers discuss employment and other issues on an Internet bulletin board. For example, the YSN recently posted an open letter that said, in part: "Jobs in research are more than scarce today: advertised research positions routinely attract hundreds of excellent applicants." The tone of the letter carried the urgency and anxiety that the committee heard during panel discussions with members of the YSN and with other young scientists and engineers.

The changes in the employment market described earlier suggest that the most effective graduate-education programs are the ones that prepare students not only for independent careers in academic research, but also for nontraditional employment in a variety of nonacademic settings (see Box 2-5). Universities and their professors need to revise the science and engineering graduate curriculum so that students are educated and prepared for the opportunities available. For example, although employers prefer to hire people who have a strong background in basic

These are some nontraditional positions and employment sectors identified for physicists with graduate degrees (APS, 1994). A list could be developed for other fields.

Medicine: medical-physics practitioner, radiological technician, CAT scan and MRI technician.
City, state, and federal government: science adviser, science attache, state-level educator or administrator, transportation staff, environment staff, statistics personnel, computational staff, World Bank staff, international trade personnel, International Atomic Energy Commission (UN) staff.
Computing: software developer, business-data handler, securities broker, banking personnel.
Small business: consultant, computational staff, forecaster, data analyzer, instrumentation expert, indexer, abstracting staff.
Law: patent attorney, expert witness.
Education: precollege teacher, community and technical college staff, museum staff, librarian, educational-materials developer, district-level school administrator.
Science journalism: newspaper journalists, scientific journalist.

Box 2-5: Nontraditional Positions and Employment Sectors

principles and reasoning, graduate research activities often focus on specialized training and techniques.

In addition, more opportunities are available to graduates who are flexible enough to shift careers. The field that is "hot" when a student enters graduate school might cool by the time of graduation. The first permanent job will seldom be the last, as workers in all fields are expected to change positions and even careers with greater frequency. Job-seekers who do not limit their educational preparation—or their job search—to traditional research positions might be better able to take advantage of a vocational environment that is changing rapidly.

As indicated in Appendix F, committee testimony and written comments from a variety of employers supported that point of view—that employers favor potential employees who

- Can collaborate across disciplines, in various settings, and learn in fields beyond their specialty.
- Can adapt quickly under changing conditions.
- Work well in teams and demonstrate leadership ability.
- Can work with people whose languages and cultures are different from their own.

In some cases, multiple advanced degrees or multidisciplinary backgrounds will be useful. For example, a student who combines a degree in life sciences with a law degree might be well qualified for the specialty of patent law within biotechnology. Likewise, a minor in geology might help an ecologist to obtain employment. Other growing multidisciplinary fields are biostatistics, numerical analysis, operations research, and digital signal processing. In some fields, single projects require multiple skills. For example, engineers with specialties in interdisciplinary fields like transportation are more likely to find employment than their mechanical- or civil-engineering counterparts.

Others have emphasized the extent to which strong scientific training—with its emphasis on analytical problem-solving, experimental strategy, and creativity—prepares a person for productive roles in government, business, and industry beyond roles that require the specific scientific or technical expertise acquired in the education process.

It is impossible to predict whether the rapid growth of traditional positions will resume during the 1990s, as was widely predicted in the late 1980s (Atkinson, 1990; Bowen and Sosa, 1989; NSF, 1989). History has shown that employment trends for graduate scientists and engineers are particularly difficult to forecast (Fechter, 1990; Leslie and Oaxaca, 1990; Vetter, 1993). Public spending on R&D and employment of scientists and engineers can change suddenly in response to unexpected events, such as the launching of Sputnik in 1957 and the collapse of the Soviet Union and the economic recession of the early 1990s. The continuing debate over employment of scientists and engineers clearly requires a continuing re-evaluation of the graduate education and training of scientists and engineers.

3

THE EDUCATION OF GRADUATE SCIENTISTS AND ENGINEERS

3.1 OVERVIEW

The recent increase in annual production of scientists and engineers with graduate degrees extends a trend of steady growth.

In 1993, more than 25,000 scientists and engineers received PhDs from US universities, up from about 18,400 in 1983 (NSF, 1994f). In the same year, some 80,000 scientists and engineers received master's degrees from US universities (including those who intended to continue toward the PhD degree), a number that has increased steadily from about 65,000 a year in the early 1980s (NSF, 1994b).

Most of the recent increase in the number of science and engineering PhDs awarded annually can be accounted for by an influx of foreign students (discussed later in this chapter). Including those students, average growth in the total science and engineering graduate-student population has averaged about 2.5% per year since 1982. The total number of graduate students in science and engineering in the United States rose from 339,600 in 1982 to 431,600 in 1992, an increase of 27% (Table 5 in NSF, 1994a). Figure 3-1 shows this growth by major field.

In 1992, most graduate science and engineering students (87%) were enrolled in universities that grant doctorates, a percentage that has varied only slightly since the Survey of Doctorate Recipients began in 1975 (NSF, 1994a). Most (67%) were full-time students.

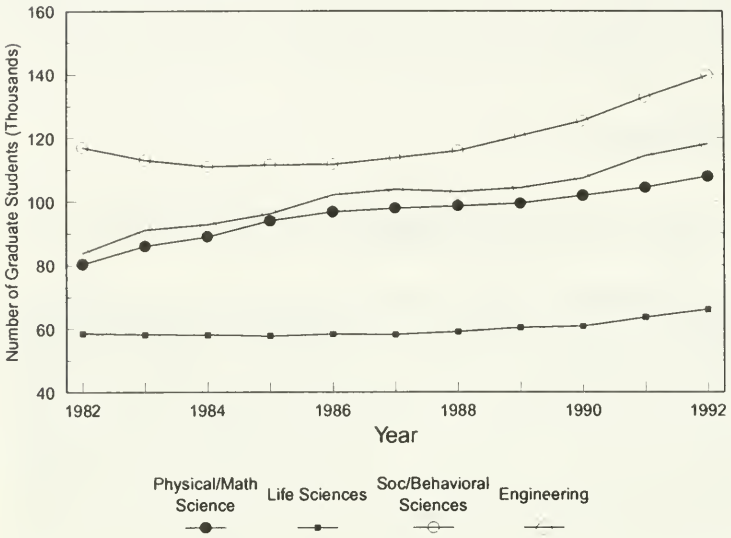

FIGURE 3-1 Science and engineering graduate student enrollment, by broad field, 1982-1992.

SOURCE: Calculated from NSF, 1994a:Table 1

NOTES: The broad fields are defined as in the notes to Figure 1-1

3.2 THE MASTER'S EXPERIENCE

In some fields, a master's degree is the professional norm.

A master's degree generally entails 2 years of coursework. Some master's-degree programs require a research thesis, others do not. In the latter case, the master's degree is not so much a terminal degree as a recognition of the coursework and qualifying examinations completed after about 2 years in a doctoral program.

In recent decades, the 2-year master's degree has served in some fields as the terminal degree. For example, the American Society for Engineering Education in 1987 reaffirmed the appropriateness of the master's degree for engineering students not expecting to enter careers in research or university teaching (ASEE, 1987). About 4.6 times as many master's degrees in engineering are awarded each year as engineering PhDs (for comparison, the ratio in the physical sciences is close to unity) (NSF, 1994b). The master's degree is also a customary end point in public health, computer science, and bioengineering and for those who want to teach in high schools and community colleges.

Data on the number of master's degrees by field, sex, race, and citizenship are included in Tables B-16 through B-19 in Appendix B and on the employment of new master's-degree recipients in Appendix C.

3.3 THE DOCTORAL EXPERIENCE

Acquisition of research skills is central to the doctoral experience.

The typical PhD program constitutes a two-part experience of great depth and intensity that lasts 4 or more years. The first part consists of about 2 years of course work. The second part focuses on a doctoral dissertation based on original research that might take 2 or 3 years or more to complete. The dissertation, as a demonstration of ability to carry out independent research, is the central exercise of the PhD program. When completed, it is expected to describe in detail the student's research and results, the relevance of that research to previous work, and the importance of the results in extending understanding of the topic (CGS, 1990).

It is customary in most fields of science and engineering for a doctoral candidate to be invited to work as a research assistant (RA) on the project of a faculty member; an aspect of this research project often becomes the subject of the student's dissertation. A traditional expectation of many students (and their professors) is that they will extend this work by becoming university faculty members. If they do, promotion and tenure depend to a great extent on continuing research publication.

A properly structured requirement for demonstrated ability to perform independent research continues to be the most effective means to prepare bright and motivated people for

research careers. Original research demands high standards, perseverance, and a first-hand understanding of evidence, controls, and problem-solving, all of which have value in a wide array of professional careers.

In the course of their dissertation research, doctoral students perform much of the work of faculty research projects and some of the university's teaching. Therefore, institutions and individual professors have incentives to accept and help to educate as many graduate (and postdoctoral) researchers as they can support on research grants, teaching assistantships, and other sources of funding. By the time they receive PhDs, 63% of science and engineering graduate students have been RAs and half have been teaching assistants. This system is advantageous for institutions, to which it brings motivated students, outside funding, and the prestige of original research programs. And it is advantageous for the graduate students, for whom it supports an original research experience as part of their education.

Although the research component of the doctoral experience is dominant, other components are also important. They include a comprehensive knowledge of the current state of knowledge and techniques in a field and an informed approach to career preparation. Because of the recent trend toward large group projects in some disciplines—in which a research topic is divided among a number of students, postdoctoral fellows, and faculty—a PhD candidate can become so focused on a particular technique that there might be little opportunity for independent exploration of related fields or career options. When a graduate student becomes essential to a larger research project, completion of the degree can be unduly delayed. Furthermore, students working on tightly focused research might conclude that this is the only valued achievement for scientists and engineers.

Carnegie-Mellon University in Pittsburgh is one institution that is experimenting with a number of reforms. Paul Christiano, provost of the university, offered the committee a summary of trends affecting graduate education in science and engineering:

- More cross-fertilization between disciplines to exploit new opportunities.
- Somewhat greater emphasis on master's-degree programs.
- Greater interest in advanced nondegree programs.
- More teaching practice for faculty and graduate students, complemented by a new teaching center.

Dr. Christiano said that new commercial and societal needs invite innovative approaches to graduate education. He cited a need for more interdisciplinary programs and for an appreciation of the value of graduate education by potential students and employers.

He also identified some obstacles to change, including reduced interest of US students in science and engineering, institutional inertia, and the short-term view of industry sponsors. For example, in the case of industry, he has found that graduates of Carnegie-Mellon's research center for engineering design have not always been well accepted by some employers, because its graduates are not linked to a traditional field. He felt that such obstacles could be reduced by better communication and more interaction between universities and industry, which would demonstrate the benefits of interdisciplinary centers.

Box 3-1: Experimentation and obstacles to reform

In many fields, nonresearch jobs are accorded lower status by faculty; students who end up in such jobs, especially outside academe, often regard themselves as having failed (that is less true in engineering and chemistry, in which nonacademic employment is often the norm). If the number of academic-style research positions continues to level off or contract, as seems likely, a growing number of PhDs might find themselves in nonacademic careers to which they have been encouraged to give little respect.

3.4 TIME TO DEGREE

The average time to complete a doctoral degree has increased for graduate students in all science and engineering fields.

Over the last 30 years, the average time it takes graduate students to complete their doctoral programs, called the "time to degree" (TTD), has increased steadily. One measure, the median time that each year's new PhDs have been registered in graduate school, has increased in some fields by more than 30%. (The time to master's degree does not seem to have increased, although no one collects national statistics on it.)

The lengthening of the period of graduate work is accompanied by a second trend. It has become more common for new PhDs in many fields to enter a period of postdoctoral study (discussed at the end of this chapter), to work in temporary research positions, and to take 1-year faculty jobs before finding a tenure-track or other potentially permanent career-track position.

We are concerned about the increasing time spent by young scientists and engineers in launching their careers. Spending time in doctoral or postdoctoral activities might not be the most effective way to use the talents of young scientists and engineers for most employment positions. Furthermore, because of the potential financial and opportunity costs, it might discourage highly talented people from going into or staying in science and engineering.

The median number of years between receipt of the bachelor's degree and the doctorate in science and engineering has increased from 7.0 years during the 1960s to 8.7 years for those who received doctorates in 1991 (Table 5 in NSF, 1993b). Graduate students in the physical sciences have shorter-than-average overall completion times—about 7 years—and social scientists have longer-than-average completion times—about 11 years (see Figure 3-2). The remaining science and engineering fields average between 8 and 9 years.

The median time registered in doctorate programs is shorter than total TTD (the interval from receipt of a bachelor's degree to receipt of a PhD) because many graduate students take some time between college and graduate school to work, and some take time off during graduate school. Because time out between college and graduate school can be valuable for gaining work experience and more mature decision-making about careers, an increase in years from bachelor's

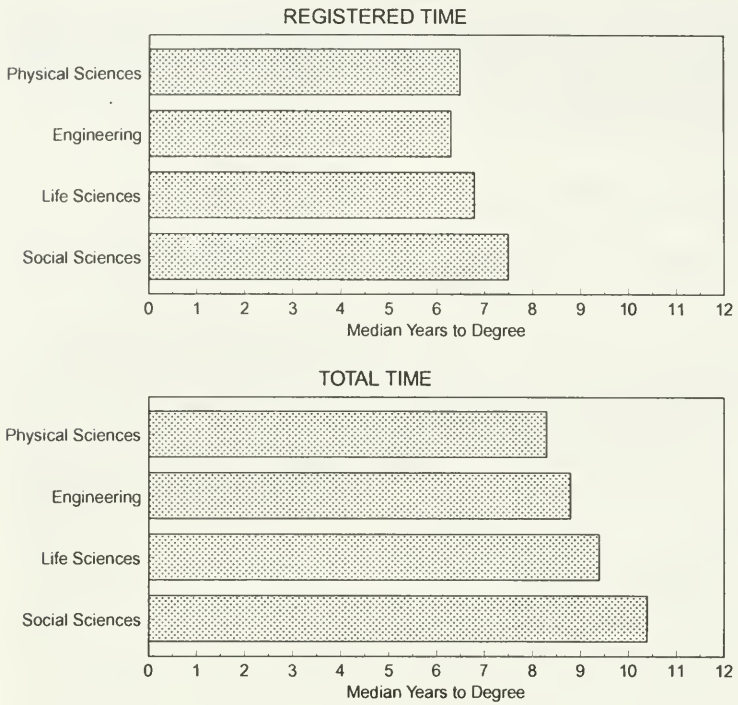

FIGURE 3-2 Median years to degree for doctorate recipients, by broad field, 1993.

SOURCE: Appendix Table B-29.

NOTES. *Total time* is the number of years between receipt of the bachelor's degree and receipt of the PhD.

Registered time is the amount of time actually enrolled in graduate school (thus, it might be less than the time elapsed from entry into graduate school and completion of the PhD).

degree to doctorate is not a problem. But registered time to degree (RTTD)[1] has also increased steadily over the last 30 years. The median RTTD for engineering PhDs increased from 5.0 years in 1962 to 6.2 years in 1992. In 1992, it was 6.7 years for PhDs in the life sciences, 6.5 years in the physical sciences, and 7.5 for the social sciences (Table 6 in NRC, 1993).

Our understanding of factors that affect TTD is incomplete. One finding, reported for psychology, is that TTDs are longer when there are many students per faculty member or many students overall (Striker, 1994). The National Research Council's Office of Scientific and Engineering Personnel in 1990 tested a five-variable model over 11 fields of science and could find no cause or set of causes to explain the trend (Striker, 1994; Tuckman et al., 1990).

Some researchers explain the increase in TTDs by pointing to the increasing complexity and quantity of knowledge required for expertise in a given field. Another possible explanation is the tendency of some faculty to extend the time that students spend on research projects beyond what is necessary to meet appropriate requirements for a dissertation. The Council of Graduate Schools (CGS) reports that lack of financial support during the dissertation phase substantially extends TTD, as do difficulties in topic selection, unrealistic expectations for the amount of work that can be completed in a dissertation, and inadequate guidance by advisers. Still other reasons are poor undergraduate preparation, student reluctance to leave the congenial life of academe, and postponement of graduation in the face of uncertain employment prospects (CGS, 1990).

There has been little research on how students spend the extra time that they take to earn a degree—whether in classwork, studying for general examinations, doing thesis research, working as teaching assistants or research assistants, etc. In a tight labor market, students might hope that the extra time might provide them with a better thesis and thus a better chance at a research position, but information on this is not readily available.

3.5 MECHANISMS OF ASSISTANCE FOR GRADUATE EDUCATION

Research grants, whose primary purpose is to support research, exert a powerful influence on the format of graduate education.

Table 3-1 provides an overview of the sources of graduate school support for doctorate recipients by broad field in 1993. Master's-degree students are mainly self-supporting (and often hold full-time jobs while studying), but most PhD students offset the cost of graduate education with grants and other forms of support from state and federal governments, industries, universities, nonprofit groups, and others. The amount and kind of support vary widely by field (see Appendix B, Table B-7).

[1] *Registered time* is the amount of time actually enrolled in graduate school (thus, it might be less than the time elapsed from entry into graduate school and completion of the PhD).

TABLE 3-1 **Source of Graduate-School Support for Doctorate Recipients, by Broad Field, 1993**

	Total		Physical Sciences		Engineering		Life Sciences		Social Sciences	
CATEGORY	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total	Number	Percent of Total
Federal Fellow/Trainee	2,352	6.3	215	3.5	132	2.5	1,360	19.4	445	7.3
GI Bill	412	1.1	35	0.6	36	0.7	53	0.8	105	1.7
Other Federal Support+	1,647	4.4	314	5.1	234	4.4	320	4.6	325	5.3
State Government	393	1.1	47	0.8	37	0.7	94	1.3	79	1.3
Foreign Government	1,631	4.4	236	3.8	402	7.5	339	4.8	247	4.0
National Fellow (nonfederal)	1,953	5.2	223	3.6	189	3.5	351	5.0	441	7.2
University Teaching Assistant	19,407	52.0	4,510	73.5	2,392	44.7	2,789	39.8	3,650	59.8
University Research Assistant+	19,564	52.4	4,714	76.8	4,211	78.7	4,604	65.7	2,934	48.1
University Fellow	6,328	16.9	967	15.7	643	12.0	1,088	15.5	1,347	22.1
Other University	4,145	11.1	312	5.1	282	5.3	642	9.2	975	16.0
Business/Employer	2,538	6.8	351	5.7	453	8.5	308	4.4	337	5.5
Own Earnings	21,537	57.7	2,073	33.8	1,912	35.7	3,088	44.1	4,331	71.0
Spouse's Earnings	10,789	28.9	1,180	19.2	878	16.4	1,847	26.4	2,082	34.1
Family Support	9,659	25.9	1,316	21.4	1,526	28.5	1,605	22.9	2,045	33.5
Guaranteed Student Loan (Stafford)	8,522	22.8	827	13.5	469	8.8	1,428	20.4	2,474	40.6
Perkins Loan (NDSL)	2,193	5.9	152	2.5	93	1.7	275	3.9	780	12.8
Other Loans	1,349	3.6	116	1.9	92	1.7	181	2.6	411	6.7
Other Sources	1,621	4.3	159	2.6	179	3.3	365	5.2	307	5.0
Unduplicated Total*	37,344		6,140		5,349		7,004		6,101	

NOTE: In this table a recipient counts once in each source category from which he or she received support. Since students indicate multiple sources of support, the vertical percentages sum to more than 100%.

+ Because federal support obtained through the university cannot always be determined, no distinction is made between federal and university research assistants in this table. Both types of support are grouped under "University Research Assistant." Federal loans are counted in the categories for loans.

* The 2,410 PhDs who did not report sources of support are omitted from this total. Percentages are based only on known responses.

SOURCE: NRC, 1995

In 1992, according to a survey of graduate departments, 41% of the 126,000 full-time graduate science and engineering students received their primary support from their institutions, 31% provided most of their own funds (including funds from federally guaranteed loans), and 20% depended primarily on federal sources, primarily in the form of research assistantships, graduate fellowships, and training-grant positions (Table 12 in NSF, 1994a). However, federal support for students in the biological and physical sciences was higher (34% and 36%, respectively). One-fourth of those with institutional support received it in the form of research assistantships, half received teaching assistantships, and the remaining one-fourth were supported by a mix of fellowships, traineeships, and other forms of support.

The preceding discussion underestimates the importance of federal support, especially to RAs, because they were measured at one time (1992). Typically, graduate students depend on different sources of support in different phases of graduate work—perhaps as teaching assistants (TAs) in the first 2 years and then as RAs while doing dissertation research. By the time students receive the doctorate, nearly two-thirds have been RAs and half TAs (see Figure 3-3). The students reporting this information are not always sure of the ultimate source of their RA funds, and the reported data do not distinguish between federal and institutional RAs (Table A-5 in NRC, 1993). But we believe that most RAs are supported by federal research grants and contracts.

Since the early 1970s, virtually all growth in federal support of scientists and engineers in academe has been in the form of grants, contracts, and cooperative agreements for R&D projects (Figure 3-4). Federal fellowship and traineeship programs were cut back substantially in the early 1970s. The research-assistantship mechanism began to grow in importance as faculty used their research grants to support graduate students. Federal support of graduate fellowships and traineeships fell steadily as a percentage of overall federal funding (Figure 3-5). **As a result, the federal government has supported graduate education for the last 2 decades primarily through its support of faculty research projects, rather than direct support of graduate students.**

There are no clear guidelines for distributing the various types of federal support. The research assistantship has become dominant, but not as a result of an education policy. The number of PhDs produced now reflects more closely the availability of research funds than the employment demand for PhDs. There are several drawbacks to this dependence on research grants. One is that the pressure to produce new research results extends to graduate students, who easily gain the impression that hard, goal-oriented work on a specific project is the most important aspect of graduate education. As already noted, PhD students can become so involved in the work of the faculty investigators under whose grants they conduct their dissertation research that little time is left for independent exploration or other educational activities. Even the best-intentioned professors might lack the time to impart a broad appreciation of their discipline or to encourage their RAs to investigate the discipline thoroughly or plan their careers. Efforts should continue to be made to make this experience as profitable and broadening as possible so that graduate scientists and engineers are prepared for all kinds of careers.

In addition, the peer-review process, effective as it is at judging the research ability of academic researchers, does not try to evaluate the educational value of the research projects that can constitute the central activities of graduate students (although contribution to education is

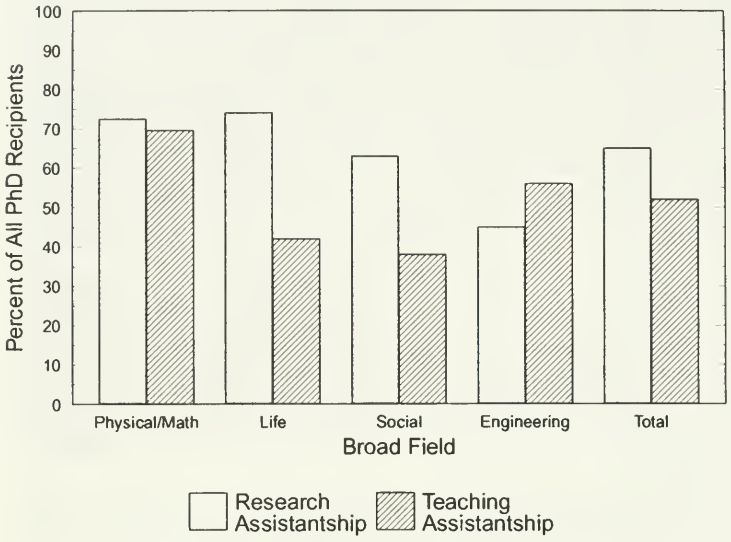

FIGURE 3-3 Incidence of research assistantships and teaching assistantships among US PhDs, by broad field, 1993

SOURCE: NRC, 1995:Table A-5.

NOTES: 1993 doctoral recipients also reported many other sources of support (see Table 3-1).

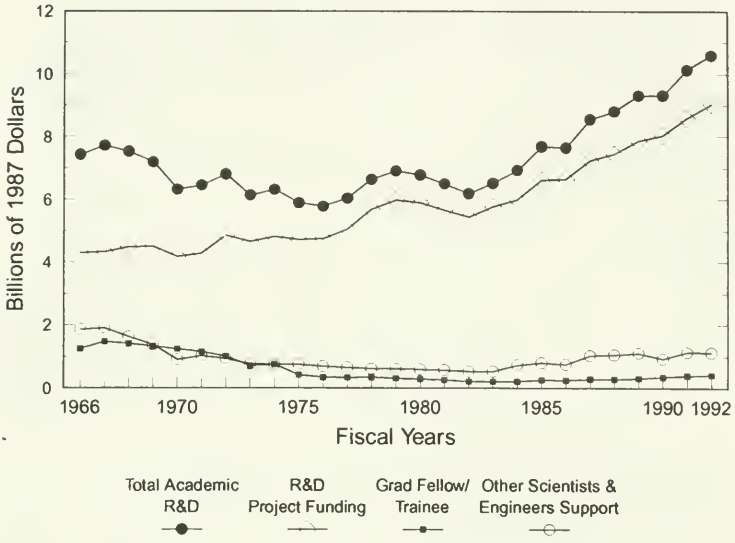

FIGURE 3-4 Types of support for academic R&D, 1966-1992 (billions of 1987 dollars).

SOURCE: NSF, 1994c:Table 5.

NOTES: Research assistantships are included as part of R&D projects. Other includes R&D plant, scientists and engineers facilities, general scientists and engineers support, and other scientists and engineers activities.

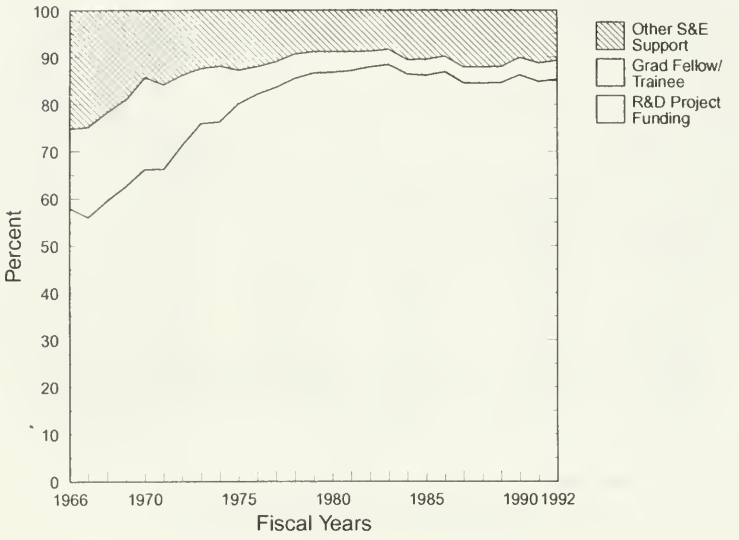

FIGURE 3-5 Mix of federal support for academic scientists and engineers, 1966-1992

SOURCE: NSF, 1994c:Table 5

NOTES: Research assistantships are included as part of R&D projects. Other includes R&D plant, scientists and engineers facilities, general scientists and engineers support, and other scientists and engineers activities.

technically one of four criteria used to judge National Science Foundation grants). And a project or research environment of high educational merit will not necessarily impress a peer-review committee charged with judging the scientific merit of a proposed research topic and the ability of a principal investigator to carry it out.

3.6 CAREER INFORMATION AND GUIDANCE

Graduate students do not routinely receive accurate, timely, and complete information on the array of available careers in science and engineering.

Several government agencies and private organizations collect and publish information relevant to the careers of graduate students, including the National Science Foundation, the Bureau of Labor Statistics, and the National Research Council. Those data are of interest to three more or less distinct communities:

- The professionals who generate the data, including universities, professors, students, and professional societies.
- The National Science Foundation, which arranges and presents data to be used by others.
- A small number of people who study and use human-resources data.

In general, the data that are available are not presented in formats designed for use by students or faculty advisers in choosing and planning careers in science and engineering. Moreover, in most cases, there is a lag of several years between the gathering of data and their publication. As a result, graduate students lack adequate information to

New employment trends are already obliging some universities to pay more attention to PhD placement. Theodore Poehler, vice provost for research at Johns Hopkins University, told the committee that his university used to pay little attention to placement of graduate scientists and engineers. However, now that they are paying more attention, they are finding that one incentive for doing so is that increasing numbers of students are considering unconventional careers. For example, of the six new PhDs in one graduate program at Hopkins last year (three US women, three foreign men), two went to small companies, two went to postdoctoral positions, one had numerous offers from around the world, and one became a NASA program manager.

Because of that experience, Johns Hopkins is trying to provide graduate students with more educational options to prepare them for a wider range of career opportunities. For example, the university offers more faculty and graduate students more opportunities for interdisciplinary research and education and for "life-long learning."

In addition, when funding is available, the university encourages graduate students to travel to national meetings where they can present their research results and to workshops where they can meet representatives of small companies and other potential employers.

Box 3-2: Enhancing Graduate Student Career Opportunities

- Design their own education and career-development strategies.
- Gain a realistic understanding of employment prospects.
- Recognize likely future demand for scientists and engineers, by field.
- Understand the dynamics, structure, and evolution of the scientific-research system.

More-effective guidance is clearly required. A prevailing belief in higher education is that faculty members "naturally" know how to be dissertation advisers through their own experience as students and teachers. That might be true when it comes to advising students who will enter academic careers, but many (if not most) faculty members have little experience with or awareness of nonacademic job opportunities and so cannot be effective advisers for other students.

3.7 THE GRADUATE EDUCATION OF WOMEN AND MINORITY-GROUP STUDENTS

The presence of women and minority-group students, although increasing, is still small relative to the population as a whole in nearly all science and engineering fields. In the long run, it is in the interest of all to recruit a fair share of the most-able members of society into science and engineering. Meanwhile, efforts should continue to ensure that all people with talent have an equal opportunity to enter science and engineering careers.

Women and minorities are underrepresented as graduate students and particularly as

Feniosky Pena, a doctoral candidate in engineering at MIT who is performing an internship with industry, told the committee that he experienced a troublesome culture gap when he began his studies.

As a native of the Dominican Republic, he had been taught to respect authority. At MIT, he was reluctant to question his adviser, who in turn thought that Mr. Pena lacked a grasp of his subject. Furthermore, the adviser used a technique of persistent interrogation, which Mr. Pena found humiliating. He heard this difficulty described by others at minority-group conferences, where students told him that they felt "stupid" when dealing with their advisers, classmates, or teachers.

He suggested that if faculty were familiar with other cultures, such misunderstandings could be avoided. He said that minority-group students need more "nurturing" if they are to reach a good understanding of the education environment in the United States.

Mr. Pena added that the racial diversity that minority-group members bring to campuses is not valued by everyone. He suggested training for both the minority and the majority so that each gains a better understanding of the other's culture.

Box 3-3: Minority Issues: the Culture Gap

faculty, researchers, academic officers, administrators, and policy-makers. The proportion of new entrants into the workforce who are minority-group members and women has risen and will continue to rise, and the quality and extent of their education should have high national priority.

Statistically, the position of **women students** in advanced science and engineering is improving, in part because of special efforts. From 1982 to 1992, the total number of women in graduate schools rose by about 3% a year, compared with a rise of 1% a year for men. In 1982, women received 23.7% of science and engineering doctorates; in 1992, they received 28.5% (see Appendix B, Table B-22). In 1993, women constituted 33% of all full-time faculty (and 37% of combined full-time and part-time faculty) but only 6% of the full-time faculty in engineering, 20% in the natural sciences, and 27% in the social sciences (Table 6 in NCES, 1994).

Linda Wilson, president of Radcliffe College, was asked by the committee to comment on issues pertaining to women in graduate science and engineering education. Dr. Wilson chairs the National Research Council's Office of Scientific and Engineering Personnel.

Dr. Wilson said that the unsatisfactory position of women in graduate education indicates the need to change the system for both men and women, both minority and majority. In her view, the key elements requiring improvement are access, including expectations and encouragement; mentoring and career guidance; recognition and respect; and accurate information about career paths.

She recommends changing the university into a more supportive culture, moving toward a "continuous learning system," and maximizing our "human capital investment" by including more women and minority-group members throughout the science and engineering enterprise.

Dr. Wilson said that key assumptions about graduate school are seldom tested, such as the notion that scientists do their best work when young and that independent work is more important than collaborative work. She suggested that more careful scrutiny of such assumptions might lead to constructive policy changes.

Box 3-4: Improving access for women and minority-group students

Women have been most successful at entering the social and life sciences. In 1992, 54% of graduate students in the social sciences and 44% of those in the life sciences were women (see Appendix B, Table B-3). Fewer women enroll in the physical sciences or engineering. In 1992, 15% of engineering graduate students and 27% of those in the natural sciences were women, but their percentage gains over the preceding decade have been greatest in those fields.

Entry into science and engineering graduate schools is lowest among **minority-group students**. The percentage of science and engineering doctorates awarded to members of underrepresented minorities increased from only 4.1% in 1982 to only 5.5% in 1992 (see Appendix B, Table B-24). In 1992, fewer than 29,000 (9%) of science and engineering graduate students were US citizens who belonged to underrepresented minorities (black, Hispanic, and American Indian) (see Appendix B, Table B-4). That is related to their low representation on college faculties: 8% of full-time faculty in 1993—6% in engineering, 7% in the natural sciences, and more than 9% in the social science (Table 6 in NCES, 1994). By comparison, in 1991, 22% of Americans were black, Hispanic, or American Indian. Committee witnesses indicated that a "critical mass" of students is particularly important for minority-group members, who as students often suffer from a "one and only" syndrome.

As the demographics of the workplace shift rapidly, it is clearly in the national interest to encourage and facilitate the entry of women and minority-group members, with white men, into science and engineering fields.

3.8 FOREIGN GRADUATE STUDENTS

The number of foreign science and engineering students enrolled in US graduate schools and the number receiving PhDs have both risen more rapidly than the comparable numbers of US citizens.

The number of science and engineering doctorates earned annually by people who are not US citizens and have temporary visas increased sharply from 3,400 in 1983 to almost 8,100 in 1993. This group received 18.5% of the doctorates in 1982 and 32% in 1992 (see Appendix B, Table B-25) and accounted for most of the net increase in the number of doctorates awarded since 1986 (see Figure 1-2).

Overall enrollment of scientists and engineers grew by just over 2% a year from 1982 to 1992, but foreign enrollment grew by more than 5% a year. Foreign participation varies widely by field: non-US citizens make up 46% of all full-time graduate students in engineering, 39% of those in the physical and mathematical sciences, 27% of those in the life sciences, and 17% of those in the social sciences.

In 1992, foreign students earned more than half the new PhDs in engineering (up from 39% 10 years earlier), more than one-third of the PhDs in physical and mathematical sciences, and one-fourth of those in the life sciences.

Box 3-5: Distribution of Foreign Graduate Students

One reason for the marked increase has been a series of political events that have encouraged in immigration. The Immigration Reform Act of 1990 gave visa preference to applicants with science and engineering skills (NSB, 1993). The arrival of many of those students results from one-time political events, but American universities continue to attract students for whom comparable education is not available at home. The issues raised by the increase in the number of foreign students in American graduate schools and earning US doctorates are discussed in Chapter 4 (Section 4.2). As discussed in Chapter 4, the decision of an increasing number of those students to seek permanent jobs in the United States increases the talent available to our country, although it adds to the employment-related pressures on advanced scientists and engineers.

3.9 POSTDOCTORAL EDUCATION

The postdoctoral population has increased faster than the graduate-student population. Some of the increase might be due to employment difficulties.

According to the latest National Science Foundation (NSF) survey of science and engineering graduate departments (unpublished), there were 24,024 science and engineering postdoctoral appointees[2] in doctorate-granting institutions in the fall of 1992, compared with 14,672 in 1982—a 63.7% increase, compared with a 26.7% increase in the number of graduate students. Part of the growth can be assumed to reflect the legitimate need for postdoctoral study and exploration to prepare for the increased complexity of modern science; in biology, chemistry, and physics, for example, postdoctoral study has become the norm. But committee testimony and other anecdotal evidence indicates that many postdoctoral appointees are extending their studies because permanent positions in academic or industrial research are not available.

An important additional factor is the increasing percentage of postdoctoral appointees who are foreign students—53% in 1992, compared with 42% in 1985 (NSF, unpublished). More foreign citizens than American citizens have had postdoctoral appointments in US universities since 1991 (Tables C-29 and C-30 in NSF, 1993a).

However, surveys do not determine the extent to which young scientists and engineers take postdoctoral positions because they cannot find regular employment. One measure of the impact of employment-market problems on the growth of the postdoctoral pool would be an increase in the length of postdoctoral time before a permanent position is found or an increase in the percentage of scientists and engineers who take second or third postdoctoral positions. Another indication would be an increasing percentage of scientists and engineers taking postdoctoral appointments at the institutions where they received their doctorates; this would indicate that professors are retaining their former students as RAs when they cannot find regular jobs.

The Survey of Doctorate Recipients can be analyzed to address the question. The comparative analysis of cohorts of scientists and engineers 5-8 years after receipt of their PhDs, done for this report, indicated that the percentage still in postdoctoral positions grew from 2% in 1977 to 3% in 1989; the increase was greater and smaller in specific fields (see Appendix C, Table C-2).[3] In 1979, more than 600 (4.9%) of the biologists who received PhDs in 1971-1974 held postdoctoral appointments; in 1989, nearly 1,300 (9.2%) of those with PhDs from 1981-1984 were in postdoctoral positions. The percentage of each cohort in the faculty tenure system fell from 40% in 1979 to 25% in 1989.

The above changes might partially explain the finding that the percentage of young biologists (aged 36 and younger) who applied to the National Institutes of Health for individual-investigator research grants fell by 54% from 1985 to 1993 (NRC, 1994a); clearly, fewer of them were in a position of independent investigator, from which they are permitted to apply for research grants.

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[2] Both numbers include foreign citizens, but the postdoctoral total includes doctorates in science or engineering from foreign universities. Part of the larger increase in the number of postdoctoral fellows over the last decade, therefore, might be ascribed to a greater propensity of foreign scientists and engineers to immigrate at the postdoctoral than the predoctoral stage, rather than to an increase in the pool of postdoctoral fellows who cannot find a job.

[3] The 1989 data from the Survey of Doctorate Recipients are used because, owing to a change in the timing of the survey, the 1991 data on postdoctoral appointments are not comparable.

Regardless of the proportion of postdoctoral appointees who are in a vocational "holding pattern," their numbers are rising, and each year they vie with the new class of graduating PhDs for available positions. The postdoctoral appointees have an advantage in being able to offer more research experience and publications in competing for available research positions. That competition, in turn, increases the trends among new PhDs toward postdoctoral study and nontraditional jobs.

4

DISCUSSION OF MAJOR RELATED ISSUES

Three of the issues raised in Chapters 2 and 3 (whether the United States is producing too many science and engineering doctorates, the effect of enrollment of foreigners, and the long time from starting graduate study to first job) are closely related to the design of graduate-education programs for scientists and engineers. Those contemporary issues have been discussed extensively by the committee and by the witnesses and correspondents who have contributed to the content of this report. Each of these related topics deserves extended study and debate in its own right. We present the issues and their possible implications for graduate-education programs in this chapter.

4.1 THE "RIGHT" NUMBER OF SCIENCE AND ENGINEERING PHDS

Having read accounts of scarcity in academic research positions, some readers might expect this report to conclude that we are producing too many PhDs and should take immediate steps to cut back PhD programs in science and engineering. We are aware of the reports of unemployment and underemployment among new doctorate recipients, and survey data indicate that recent PhDs are finding it harder to make the transition from graduate school and postdoctoral study to career positions (see Chapter 2). The current situation probably results in part from the increase in annual PhD production to 25,000 in 1993 from the 18,000-19,000 per year in 1976-1986. In response, some graduate programs have begun to accept fewer new students. But forecasting demand for science and engineering PhDs is difficult, and, because it takes a long time for changes in graduate enrollment to manifest themselves in PhDs, past efforts either to increase production in response to perceived shortages (in the 1960s and 1980s) or to reduce production (in the 1970s) ended up not having beneficial effects, in that graduate

students and programs had already made substantial adjustments. Because of the lag times between policy action and changes in the system and for reasons enumerated below, we do not think it possible to determine appropriate production targets. A better way to keep supply and demand in balance appears in the next chapter.

The Current Unemployment Situation

The committee is not convinced that the current low and stable unemployment rates among science and engineering PhDs, even new ones, that are documented in Chapter 2 prove that the system is working as well as it should. It is true that science and engineering PhDs have prospered in an increasingly diverse labor market. But as we illustrated in Chapter 2, there are indications of employment difficulties, especially for recent graduates. For example, the percentage of scientists and engineers looking for jobs in the first months after PhD receipt has risen dramatically in some fields, and there is evidence that an increasing percentage of those counted as "employed PhDs" have taken temporary positions in either postdoctoral fellowships or short-term jobs. The unemployment rate as of 1993 (the last year for which there were national data) was still low at 1.6% but was increased from the roughly 1.0% of the 1980s and 1.4% in 1991 (Figure 2-3). Unemployment among new science and engineering PhDs reached 2% in 1993, compared with the roughly 1.5% of the 1980s.

Nor do the available employment data take into account the nature of jobs held by recent PhD recipients. Statistically, a PhD physicist working in a job outside science and engineering is counted equally with a physicist on the staff of AT&T Bell Laboratories or a tenure-track assistant professor at a research university. Moreover, some PhDs who are finding good jobs in nontraditional fields might be doing so regardless of their PhD training, not because of it. The predominant view of the employers that we heard from during the course of our study was that PhD work, including original research, made students more effective employees. However, these graduates might be attractive to some employers simply because they are members of a highly qualified, hard-working, and carefully selected group of people. The time spent in or the content of a PhD program might not be well matched to some science and engineering graduates' jobs.

The committee cannot measure employment difficulties precisely, but the evidence received from witnesses and other contributors is persuasive that problems exist in at least some sectors. Some recent PhDs have indicated that they regretted having spent time and money on doctoral work that turned out not to be useful in their permanent jobs. Some even reported "hiding" their doctorates so as not to appear overqualified, unbusinesslike, or too theoretical in their approach to work.

We believe that the slow but steady shift[1] in demand for doctoral scientists and engineers over the last 2 decades away from academe and toward a greater variety of employment has

[1] This shift seems dramatic to many observers, but employment data portray slow change over the last 20 years.

accelerated somewhat in the early 1990s at the same time that the number of new graduates (many of them foreign students) has increased rapidly. For a variety of reasons, the number of academic positions and traditional industrial research positions is steady or shrinking, in accord with anecdotal reports that an unusually high number of new PhDs had to change career plans on graduating or after several years in postdoctoral positions.

To some extent, the science and engineering employment situation is cyclical, and it might already be adjusting. The recent recession ended slowly, but economic growth has resumed, and the demand for skilled people is increasing even in some industries that have undergone substantial reduction and restructuring. In addition, the high rate of increase in the number of PhDs awarded to foreign citizens in the United States, which averaged more than 12% per year in the late 1980s, began to fall after 1990 and was 0.3% in 1993 (calculated from Table 3 in NSF, 1994f). The number of doctorates awarded to foreign citizens with temporary visas fell slightly in physics/astronomy, chemistry, environmental sciences, and computer sciences from 1992 to 1993 (NRC, 1995: Appendix Table A-2).

However, we have already cited some indications of basic structural changes that lower demand, including cuts in defense spending, industrial restructuring, and reductions in growth of federal R&D spending. There is no evidence that these trends of the last several years will end soon. Thus, even if PhD production does fall in the near term, science and engineering graduate students might do well to prepare themselves for an increasingly diverse set of career paths.

Limitations of Supply-Demand Models for Forecasting Science and Engineering Personnel Needs

Supply-demand models are not now adequate for predicting whether there will be an undersupply or oversupply of trained scientists and engineers (Fechter, 1990; Leslie and Oaxaca, 1990; NSB, 1993; Vetter, 1993). That conclusion was also expressed by the panel on estimation procedures of the Committee on National Needs for Biomedical and Behavioral Research Personnel, which found that previous supply-demand models for basic biomedical, behavioral, and clinical research scientists had not proved accurate (NRC, 1994b).

At least two types of limitations of such models severely reduce their reliability, especially over the 5- to 10-year periods needed to carry out graduate-education plans. Internally, they are not based on an adequate understanding of the behavior of the students, faculty, and other people whose collective decisions affect the supply of new scientists and engineers; externally, they cannot always predict the impact of major changes in key variables outside the graduate system itself that affect demand for scientists and engineers.

For example, predictions of a huge oversupply of scientists and engineers in the early 1970s did not come true, because as a result of the predictions the students changed plans, administrators reduced programs, and graduates found new ways to use their training—all behavioral changes that were not included in the models. More recent studies have forecast

shortages of college and university faculty, beginning in the middle 1990s. These shortages have not occurred. The forecasters could not anticipate the behavioral effects of recession and tight government budgets: fewer faculty have elected to retire, and universities and colleges have begun to fill faculty openings temporarily or leave them unfilled.

As an example of unanticipated external events affecting science and engineering employment, the buildup of physical scientists and engineers in the late 1980s stimulated by increased defense spending earlier in the decade was followed by the end of the Cold War, which reduced demand for scientists and engineers; similarly, no one could predict the immigration of experienced scientists and engineers from the former Soviet Union and eastern Europe. The intensified pressures of international economic competition have also had unexpected effects, which have led some large high-technology companies to reduce their research staffs and redirect those who remain toward more-applied research with near-term payoffs.

Conclusion

With current techniques, it is not possible to forecast the future demand for or supply of scientists and engineers. We can tell with some confidence whether there are immediate mismatches between supply and demand; but in the absence of reliable long-range models, we do not know whether a situation is temporary and self-correcting or whether stronger action is required. In other words, there is little basis for trying to control the production of new science and engineering PhDs by limiting enrollments nationally through some central control mechanism.

There are ways to improve the likelihood of a balance between supply and demand that do not involve central planning and all the information requirements on which such planning depends. We believe that a combination of greater breadth and flexibility in graduate curriculums, better information and guidance, and financial support mechanisms whose primary purpose is education will provide scientists and engineers who can move more flexibly toward employment demand. Our recommendations are presented in greater detail in Chapter 5.

Meanwhile, efforts should continue to improve the collection and analysis of employment-related information by the National Science Foundation (NSF), other agencies, and the scientific societies and associations. Understanding the dynamics of and trends in career paths of scientists and engineers with advanced degrees in the various employment sectors is especially important. The results should be disseminated to prospective graduate students, to graduate students, to postdoctoral fellows, and to the faculty who advise them. Better supply-demand modeling of PhD labor markets is also important. We offer specific recommendations in Chapter 5.

4.2 THE ISSUE OF FOREIGN STUDENTS

As noted in Chapter 3, foreign-citizen students accounted for most of the increase in the numbers of science and engineering graduate students and numbers of PhDs since about 1986. In 1992, for example, foreign citizens were nearly one-third of graduate students in science and engineering, up from less than one-fourth in 1982. By 1993, 57% of the PhDs in engineering and more than one-third in physics, computer science, and mathematics were awarded to foreign-born scientists and engineers (Table 3 in NSF, 1994f). All together, the increase in foreign graduate students with temporary visas accounted for 65.5% of the net increase in annual science and engineering PhD awards 1986 to 1993, and an increase in the number of foreign-citizen PhDs with permanent visas contributed almost another 11% to the increase. Foreign citizens achieved a majority of science and engineering postdoctoral appointments in the United States in 1991.

Support of Foreign Graduate Students

Immigration laws have been changed to place some restrictions on foreign citizens with temporary student visas who are enrolled in US graduate science and engineering programs. They are required to be full-time students, and they and their dependents are prohibited from taking jobs. They are prohibited from taking most fellowships and traineeships or applying for federally guaranteed loans and other forms of direct federal assistance. They can be employed as research assistants on federally funded research projects. Many foreigners receive support for the first year of their graduate study from their home countries, but the universities usually support them after that, generally with research assistantships and teaching assistantships (much of the support comes from federal research grants) (CRS, 1992).

As a result, universities provide a greater degree of financial support to foreign students than to US citizens. In 1992, for example, universities provided support to 87% of the graduate students in the physical sciences with temporary visas, 84% of those with permanent visas, and 72% of those who were US citizens. In engineering, university support went to 76%, 73%, and 61%, respectively. The pattern was similar in the life and social sciences.

Where Do Foreign-Citizen PhDs Go?

It has been generally possible under the immigration laws for new PhDs of foreign citizenship to find entry-level positions in the US labor force (NSF, 1990b). Historically, about

half the foreign citizens with American doctorates in science and engineering have left the United States after getting their PhDs or later postdoctoral appointments (CRS, 1992).[2]

What Are the Effects?

Opinions about the effects of an increasing number and percentage of foreigners in American graduate science and engineering programs have been mixed (see CRS, 1992, for review and citations). Some people say that the United States benefits from high graduate enrollments of foreign students because they help with research and teaching, counter the declining interest of American students in science and engineering, and fill the employment needs of industrial laboratories. They argue that in a global economy, US universities and industries should be able to recruit the best talent available.[3] Some value the contribution of foreign students to a multicultural educational environment. Others point out that US companies later hire foreign students to help open new markets in their country of origin.

Other people have begun to argue that the numbers of foreign students should be limited, on several grounds. They charge that increasing numbers of foreigners with US PhDs who remain in this country (many of whom become US citizens) are competing with American graduates for jobs; that might explain some part of the employment problems that recent PhDs have complained of in the last several years. Meanwhile, some return home and work for our economic competitors. Critics of increased graduate enrollment of foreigners also have charged that cultural and language differences make many of them ineffective in the classroom and limit their ability to succeed in the labor market, that their graduate training has been unfairly subsidized by American taxpayers, that they depress salaries and thus interfere with an important market signal that would attract more American students, and that their presence discourages defense-related research in industry and on campus (CRS, 1992). A bill was introduced in 1992

[2] In addition, an unknown number of foreign citizens come to work in the United States after receiving their PhDs from foreign institutions. They are a subset of the immigrant scientists and engineers of all degree levels reported by the US Department of State to NSF. In 1992, that number jumped to nearly 23,000, compared with 11,000-12,000 a year during the 1980s (NSB, 1993:82). More than half were from East Asia, and two-thirds to three-fourths have been engineers. The increase probably resulted from the Immigration Act of 1990, which was passed in response to predictions by NSF and others in the late 1980s that a shortage of scientists and engineers was impending.

[3] It is interesting to note, for example, that approximately 20% of the individuals elected to National Academy of Sciences membership each year since World War II have been foreign-born US citizens.

in the second session of the 102nd Congress requiring universities to give preference to US students in filling federally sponsored research positions.[4]

Conclusion

The sharp jump in number of foreign-citizen graduate students in recent years, as described in Chapter 3, has probably been caused in part by a set of political events that are unlikely to recur, as well as changes in US immigration laws. And many foreign students are in the United States because their home nations lack adequate educational infrastructures. As the wealth of developing nations grows, so will these infrastructures, providing more attractive employment opportunities at home. Already, the aggregate of undergraduate science and engineering enrollments in six economically important Asian nations exceeds undergraduate science and engineering enrollment in the United States (NSF, 1993c).

The number of American students entering science and engineering graduate schools is not rising. There is no evidence that this situation would be changed by limiting foreigners. In fact, artificial limits could have the detrimental effect of disrupting the supply of scientists and engineers in key fields.

To the extent that there is a limit on the number of departmental "slots" for graduate students, we are inclined to believe that the real issue is the lack of US students, rather than the increasing presence of foreign students in our graduate science and engineering programs, but it is difficult to assess the claim that the easy access to foreign students has prevented an adequate response of the system to declining US student interest. If graduate programs are filled with foreigners, the programs do not have to make adjustments in enrollments or in content to make them more relevant to US students. Nor do businesses have to increase salaries to increase their supply of American students.

The committee suggests that the most appropriate response to flat or declining graduate enrollments of American students is to implement the measures advocated in this report, which should improve the functioning of the PhD labor market, and to continue efforts to strengthen the teaching of precollege and undergraduate science. Those measures, we believe, would make graduate education in science and engineering more attractive, more effective, and accessible to a larger group of qualified American applicants.

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[4] The American Math and Science Student Support Bill, HR 4595, was introduced on March 26, 1992. It did not pass, but neither did a bill (S 44) to allow any foreign citizens earning degrees in the natural sciences, engineering, or computer science from US institutions to obtain permanent resident visas.

4.3 TIME TO EMPLOYMENT

For a variety of reasons that are not well understood, it has been taking longer for PhDs in science and engineering to begin their careers with "potentially permanent" jobs—i.e., post-PhD jobs that are not postdoctoral fellowships and are not temporary. According to an NSF analysis of the Survey of Doctorate Recipients, the median age of PhD recipients entering their first permanent positions increased in all fields from 1971 to 1991—by more than a year for PhDs in engineering (from age 30 to 31), by 2 years in the physical and mathematical sciences (from 30 to 32), by 3 years in the life sciences (from 30 to 33), and by nearly 4 years in the social and behavioral sciences (from 30 to 34).

The committee is concerned about the longer time to first permanent job. The prospect of many years of graduate study might discourage qualified candidates from attempting a PhD. Also, extending the years of schooling burdens PhDs who enter nonacademic employment with a disadvantage compared with their contemporaries, who are years ahead in workplace experience and seniority. Finally, long times to degree (TTDs) and more postdoctoral study increase the time required for the supply of PhDs to respond to shifts in market demand; this has both social and individual costs.

There are many possible reasons for the lengthening of time to first regular position, some of them positive (e.g., time spent working between college and graduate school, which adds experience and maturity), some negative (e.g., discouragement of graduation by faculty who need research assistants or teaching assistants and an oversupply of PhDs relative to demand for academic positions), and some unavoidable (more time devoted to child-care responsibilities and a greater amount of material to learn in graduate school and in postdoctoral appointments). Increasing TTDs of all types (registered, elapsed, and total time) have been defined and documented in Chapter 3, and entering graduate students on the average are probably older to begin with. The median age of new PhDs has increased in all fields since 1971—by 1 year in physics and astronomy, by 1.5 years in engineering and chemistry, by 2 years in biology, by 2.5 years in mathematics, and by more than 3 years in the social sciences (Table 4 in NSF, 1993b). A growing proportion of graduate students come from groups that take longer to finish—women, underrepresented minorities, and foreign citizens (Stricker, 1994:570).

The committee discussed the issue of longer time to first permanent position, the possible causes, and the significance. We are concerned about the costs of increased time to first permanent position and the role of increased TTD in it, but we hesitate to recommend a particular time limit for completion of the PhD or a particular length of postdoctoral study, partly in recognition of the great diversity of graduate students, disciplinary requirements, and educational institutions missions. Instead, we believe that clearly understood quantitative guidelines for PhD completion times should be set by individual institutions after discussions among students, faculty, and professional societies.[5]

[5] Institutional policies should include criteria for exceptions to standards. For example, students who work or have children should be allowed to negotiate reasonable schedules without prejudice to their standing.

The committee notes that many institutions already have guidelines intended to limit time to degree. At the Georgia Institute of Technology, for example, chemical engineers are expected to complete a PhD in 4 years, and flexibility is granted as appropriate. Other institutions allow students to receive teaching assistantships for only 4 years; still others limit the time that a student can work on a single research project.

Whatever the institutional guidelines are, they must be implemented, monitored, and enforced to ensure that graduate students are never used to provide inexpensive labor on research projects or in teaching. As the report of the Association of American Universities/Association of Graduate Schools puts it, "policy changes alone are insufficient; the commitment to implement them is crucial" (AAU, 1990). Each institution should adopt standards appropriate to its mission and student body and should charge graduate schools and their deans with oversight. That could be done at the departmental or program level. Departmental rules should be developed with the active participation of the faculty who carry out graduate education, and they must be clearly communicated to students, faculty advisers, and dissertation committees.

4.4 INFORMATION AND ANALYSIS NEEDS

It is characteristic of the issues described in this chapter, particularly time to employment or first permanent job, that more information on and better understanding of them is needed, despite the problems and sensitivities involved in addressing the issues of employment, foreign students, and institutional policies concerning time to degree. Accordingly, appropriate recommendations aimed at NSF, which has the lead responsibility for gathering and analyzing information about the science and engineering enterprise, are included in the next chapter.

5

Conclusions and Recommendations

America's system of graduate education in science and engineering has set the international standard, especially in preparing students to work successfully at the cutting edge of research, and it must continue to do so. Graduate schools have also, increasingly in recent years, contributed to filling the nation's growing need for advanced expertise in diverse nonresearch positions.

Nevertheless, the committee believes that there is room for substantial improvement in graduate education and that some immediate changes are needed in programs, information, and attitudes. These changes are recommended, in part, in response to contemporary stresses. In many important fields, employment in basic-research positions has not kept pace with expanding graduate enrollments, and this has led to unmet expectations among many graduates who have aspired to such positions. The available evidence on unemployment rates indicates that demand by less-traditional employers is growing fast enough to absorb most graduates. However, we note broad criticism from many such employers concerning graduates' immediate suitability for entry jobs—criticism that is often based on a belief that students are too specialized, in view of the variety of tasks that they will confront, and that it is hard for them to adapt to the demands of nonacademic work. With only one-third of new PhDs expected to enter the academic tenure system, the needs of these alternate employees should be given more attention.

There is also a broader concern: Although it is clear that human resources are the primary key to the nation's strength in science and technology, we have not, as a nation, paid adequate attention to the graduate schools as a system for meeting the full range of needs for advanced talent in science and engineering. That is perhaps seen most clearly in the fact that the United States has effectively lacked human-resources policy for advanced scientists and engineers. In effect, human resources have been taken for granted as a byproduct of our policies for the support of research. The simplifying assumption—both inside and outside the university community—has been that the dominant function of graduate programs is to produce the next generation of academic researchers. It is time for a fuller recognition, by academics and policy

officials alike, of the changing way that graduate education in science and engineering contributes to the wide array of national needs. For many of these needs, it is a career in professional service, applied research, development, or consulting that graduates will find open to them.

The committee concludes that improvement of three kinds is needed. First, graduate programs should add emphasis on **versatility**; we need to make our students more adaptable to changing conditions. This is mainly a matter of local initiative by the universities themselves, but there is a supporting role for government, too. Second, much better **information** should be routinely provided to students and their advisers so that students can make more realistic career decisions than is now practical. Third, there needs to be a deliberate **national reconsideration** of graduate education so that the open policy questions, the current information gaps, and the contemporary stresses are systematically addressed by a suitable blend of university, industry, professional society, and government. Those improvements can be made without disruption of the traditional commitment to excellence in basic research that has been, and must continue to be, a hallmark of the US system of graduate education.

Although the universities are primarily responsible for implementing those changes, national and state government, industry, business, and others can help by providing opportunities to gain experience and exposure to a variety of occupations via internships, alternative certification programs, etc. We do not minimize the difficulty of effecting reform in a system as complex and diffuse as that of US universities. But we already have many relevant examples of the application of local imagination and initiative. We believe that most university leaders will find it in their own interest to reshape graduate education to meet students' career needs better and to ensure universities' vital role in the nation's steady progress toward a knowledge-based society.

5.1 NATIONAL OPTIONS

The committee arrived at its preferred national strategy—emphasizing versatility and information—after considering alternative approaches.

For example, it might seem tempting to remove any apparent imbalance between supply and demand by adjusting student enrollment. The reasons not to move toward anything like national enrollment quotas have been presented above (see Section 4.1). We found these arguments as persuasive when applied to discipline or fields as would be implied in suggestions to cut physics enrollments by X% or to increase the numbers of master's degrees in microbiology by Y%. Identifying the "right" number of graduates is chancy, to say nothing of administering nationwide compliance.

Another version of this suggestion is that we should set out to adjust the mix of master's degrees and PhD degrees that are awarded. Some question, for example, whether PhD-holders are not overeducated for the positions they fill—especially for nonresearch jobs—and whether a master's degree would suffice. But can one actually conclude that the PhD experience is

unnecessary for such positions? From the information gathered by the committee (see Section 2.7 and Appendix F), the opposite seems to be true. Employers themselves appear to be seeking the intellectual standards, resourcefulness, and initiative that come with the successful completion of original research in a PhD program. The complexity and sophistication of more and more positions appear to require the qualities gained in the advanced coursework and original-problem formation of graduate programs.

Another possibility is the creation of a new form of degree—a "different doctorate," perhaps, or a degree that is intermediate between a master's and a doctorate. In theory, a new degree could be better tuned to the class of nontraditional jobs that PhDs are increasingly filling—for example, it might require less-intensive or different types of research and dissertation experience and as a consequence take less time to complete.

In practice, however, we are convinced that this approach would not work well. The proposal is reminiscent of the doctor of science (DSc) degree that some institutions have offered with the hope that it would catch on as the preferred degree for doctoral students who seek nontraditional careers. A key point is that employers report that they value the research experience required for the PhD degree. Without ready demand for a newly introduced degree, students risk investing substantial effort only to find that they receive a diploma regarded as inferior—one that critics might think of as "PhD-lite." It is more realistic, we conclude, to adapt the PhD degree than to try to invent and introduce a hybrid degree.

In opting for a strategy of making graduates much more versatile and informed, we believe we have a solution that allows the system to self-adjust continuously in a way that does not depend on the accuracy of an assessment of the number of graduates needed in the national aggregate or in particular fields. Thus, for example, if better-informed students conclude that the PhD is inappropriate or unnecessary for the jobs they want, enrollments will decline accordingly.

5.2 TOWARD GREATER VERSATILITY

Once enrolled, a graduate student might find many reasons to select a relatively narrow subject for intensive study. A student might be fascinated by a particular field of knowledge and see specialization as the surest route to a research position. If the selected field aligns with the research interests of a professor, the student might have an exciting and educationally enriching chance to work as an assistant on a path-breaking research team; this can enrich the student's educational experience immeasurably and can provide fresh ideas and energy to the research team as well.

The disadvantages of overspecialization in graduate school, although not immediately apparent, are real for both the student and the nation, whether or not the student becomes a researcher. Excessive concentration in a particular subfield can limit a person's later research contributions and affect later career choices. It is difficult to gauge whether a specialty chosen early in graduate school will be desirable in the job market or still be in the exciting forefront

of research when the graduate years conclude. And midcareer changes might be desirable later, whether or not the person starts off in a research position; too narrow an educational experience makes later changes difficult, especially in the direction of nontraditional types of employment.

5.2.1. To produce scientists and engineers who are versatile, graduate programs should provide options that allow students to gain a wider variety of academic and other career skills.

Graduate programs should offer options that equip students for a wide array of eventual career opportunities. These options are beginning to appear on some campuses but need to be expanded to promote students' ability to adapt. Adaptability can be enhanced in two ways.

A number of universities have set up innovative programs designed to promote interactions between academe and industry. One example is the Leaders for Manufacturing Program at the Massachusetts Institute of Technology, organized around the School of Engineering and the Sloan School of Management.

The program seeks to create collaborative processes for problem identification, discovery, and knowledge transfer. It attempts to promote leadership skills (communication, motivation, decision-making, and change management), practice, and reflection. A survey of industry partners involved in the program estimated that in the first 5 years they had saved more than $28 million and incorporated 40% of the thesis work into practice.

Box 5-1: University-Industry Interactions

First, graduate students can benefit from a wider variety of **academic preparation.** For students who choose to enter a research career within the discipline studied in graduate school, it is important to have a grounding in the broad fundamentals of the field and some personal familiarity with several subfields—a breadth that might be much harder to gain after graduation. For such positions, if students become overspecialized in graduate school, they can later suffer from an inability to recognize and enter newly emerging kinds of research. For nonresearch positions, too, one's value to employers is likely to be enhanced by breadth in a related field, gained through coursework or, better, a minor. For example, a chemist might minor in computer science or a biologist in mathematics. Second, there is value in experiences that supply **career skills** beyond those gained in the laboratory and classroom. More students should, for example, have off-campus experiences to acquire the skills desired by an increasing number of employers, especially the ability to communicate complex ideas to nonspecialists and the ability to work in teams of interdependent workers.

The internship in off-campus settings is one option that needs to be expanded. Project-oriented teams in corporations provide potential opportunities for collaborative interactions and exposure to challenging practical problems. Joint industry-university projects should be explored as part of some students' preparation, with the possibility that students complete their dissertation

work off campus. Such projects also acquaint faculty members with the needs and organizational cultures of nonacademic employers.

Graduate programs should also expand on-campus opportunities to allow their students to attain a broader range of career skills. Outstanding people in a large variety of careers can be brought to campuses for presentations and made available to students. And communication skills might be sharpened through organized presentations to people outside the discipline and through older students' mentorship of younger students, for example.

5.2.2. To foster versatility, government and other agents of financial assistance for graduate students should adjust their support mechanisms to include new "education/training grants" that resemble the training grants now available in some federal agencies.

The United States has a sound tradition of investing generously in the graduate education of scientists and engineers. Federal agencies, private foundations, industries, and other granting agencies can support the efforts of both students and their graduate programs to enhance the versatility of new graduates.

> "Compared with fellowships and traineeships, research assistantships are a very imprecise instrument for producing human resources for science and engineering. First, because students are in effect bound to their faculty mentors for financial support, they have less flexibility to pursue innovative learning experiences, such as participating in collaborative research with private corporations. In addition, research funding could play a larger strategic role in developing human resources for science and technology, particularly in attracting and cultivating more students from groups in the U.S. population that have traditionally been underrepresented in science and engineering. This has taken on added importance now that the majority of new entrants to the workforce are women and [members of] minorities."
>
> Source: Good and Lane, 1994.

Most federal support for students is provided through research assistantships. Research assistantships have proved important for bringing graduate students into federally funded research projects, and they will continue to remain a major form of federal assistance.

Research assistantships can bring great educational benefits to students, but they are not specifically designed to enhance the versatility of graduate students. Assistantships are usually administered by the faculty researchers who receive the research grants, so the needs of the funded projects themselves are likely to be paramount in guiding students' work assignments.

We recommend increasing the relative emphasis on education/training grants, a concept adapted from the training grants[1] that are now awarded in selected agencies. Training grants are awarded competitively to institutions and departments, which use them to enrich students' educational experience in diverse ways. They have been used effectively to meet a variety of national objectives, and they can be tuned to the goal that we emphasize: the development and sustenance of locally conceived program innovations that enhance versatility in the graduate population. We recognize that, in a period of constrained funds, increased emphasis on education grants could reduce the number of research assistantships that are available.

The essential features of education/training grants would be:

- The grants are awarded, on the basis of competitive proposals, to *departments and programs*, rather than to individual faculty members.
- *Evaluation criteria* feature the proposer's plan to improve the versatility of students, both through program and curriculum innovations and by upgrading faculty advice to acquaint students with the full range of future employment options.

In recent years, the engineering directorate of the National Science Foundation (NSF) has developed innovative programs that support the goals outlined in this report. One example is the Industry Partnerships in Research and Education program, which includes 18 engineering research centers, 25 science-technology centers, and 53 cooperative research centers. The purpose of these activities is to increase industry-university interactions.

NSF recently announced a new program to allow students receiving NSF postdoctoral fellowships in chemistry to work in a US industrial laboratory. The purposes of the program are to facilitate the transfer of knowledge and technology between industry and academe and to give new PhDs experience in private industry. Applicants are required to negotiate agreements on intellectual property with the sponsoring company and to write a research plan that can be pursued after the fellowship is completed.

Box 5-2: New NSF Graduate-Education Initiatives

The experience with training grants at the National Institutes of Health over the last few decades shows that this type of mechanism can be successful in establishing productive interdisciplinary programs and in encouraging students to enter emerging fields of research. We encourage the growth of this program in a way that further enhances students' command of subjects and skills needed by nontraditional employers.

[1] *Training grant* is the traditional term to describe many grants to universities and departments. However, we propose the term *education/training grant* as more appropriate for the mechanism set forth in this report. The difference in meaning between education ("learning how to think and learn") and training ("learning how to do") underlies our preference for adding the word *education*. Training grants are used to meet several ends. Education/training grants, in contrast, would be aimed at one goal: greater student versatility.

The National Science Foundation (NSF) is reviving the training-grant program that it supported until the 1970s. In its initial stage, only a few hundred of the 20,000 students supported by NSF grants are receiving traineeships. By means of its training grants, NSF hopes to serve a variety of distinct purposes, including promotion of emerging fields, interdisciplinary programs, industry involvement, and the participation of women and minority-group members. We encourage deliberate expansion of this effort for the special purpose of fostering broader graduate experiences, which could well include industry involvement and emerging research that is particularly valued in expanding job markets. Some of the new education/training grants should be administered as demonstration grants for particularly innovative programs; if successful, demonstration grants should be expanded at NSF and replicated in other agencies.

What would be a "winning" education/ training-grant proposal, according to the committee? A winning proposal might include (1) an interdepartmental or program activity that would improve the versatility of graduate students, such as an interdisciplinary degree program that allowed a mathematics PhD student to obtain an MS in engineering; (2) a program element, such as an internship program, that improved the adaptability of graduate students by increasing their exposure to different ways of working in different employment sectors; (3) a program element that exposed students to the wide variety of employment opportunities open to them via career-opportunity and skill seminars, job fairs, and graduate career counseling; and (4) a program to reduce time to degree by 1 year.

One example of a winning proposal would be a grant that would be provided to both a university and an industry for a collaborative research program. One could imagine a collaborative program between the University of Washington and Boeing Corporation to develop a program in which the University of Washington would provide solid grounding in elementary and particle physics and Boeing would provide background in aerospace applications of physics. Another possibility is a grant to a university and a state K-12 authority to provide teacher leadership training in science curricula.

Box 5-3: Education/Training-Grant Proposal

Other federal agencies could use education/training grants effectively. The Atomic Energy Commission and the National Aeronautics and Space Administration once used what they called training grants to help to augment the national pool of nuclear and aerospace engineers; today, the Environmental Protection Agency and the Department of Energy, for example, could use this type of grant to induce more young researchers to address issues in environmental protection and remediation. Similarly, one goal of the recently launched technology-transfer programs—the Advanced Technology Program and the Technology Reinvestment Program—is to foster science-based technologies in industry. Those programs now operate by means of cost-shared research grants, but a worthy national objective could be the development of human resources as a component of technology transfer, and a portion of program funds could be devoted to education/training grants.

Education/training grants need not be restricted to federal agencies. For example, corporate sponsors could design grants to expose students to industrial research, development, and problem-solving. Foundations and state governments could fund graduate education/training grants with the aim of producing secondary-school teachers and science-curriculum specialists.

In summary, these suggestions are intended to encourage a **better balance** among the alternative types of grants: continuing *fellowships* for the top research-oriented students,

expanding *education/training grants* to catalyze the development of innovative programs, continuing a substantial number of *research assistantships*, and continuing institution-supported *teaching assistantships*.

5.2.3. In implementing changes to promote versatility, care must be taken not to compromise other important objectives.

Introducing measures to enhance versatility will require care and imagination. They should be instituted in a way that allows universities to attain other ends—enumerated below—at the same time.

Maintaining Local Initiative. The changes that we recommend will likely come from local institutional initiatives and should show considerable local variation. We would not expect or want all universities to offer the same or similar options to their students. Programs should build on their own strengths and interests. Some universities and departments might want to focus on particular career paths (e.g., secondary-school teaching or subject fields of interest to local business and industry). Others might emphasize the development of particular career skills or cross-disciplinary combinations. Different university programs across the United States play different roles now, and that should continue.

At Drexel University, PhD programs are relatively new. The first efforts, beginning in the 1960s, were interdisciplinary biomedical programs. Today, Drexel produces 70-80 PhDs per year, mostly in science and engineering.

An unusual aspect of the program is that students spend 18 months of the 5-year program doing cooperative work with industry. Dennis Brown, provost at Drexel, told the committee that half the full-time faculty are involved in collaborative industry-faculty research.

In Dr. Brown's opinion, today's scientists and engineers need more knowledge about business, pedagogy, multidisciplinary approaches, and policy environments. He summarized the Drexel approach as a "value-added PhD," which includes

- More intimate knowledge of business and commerce and ability to develop and market ideas.
- Less emphasis on research during graduate school and more emphasis on education.
- Interdisciplinary PhDs in such areas as environmental science and engineering and biomedicine.
- Combining traditional PhDs with policy studies through traineeship programs.

Other current efforts at Drexel include master's-degree cooperative placements, new programs in engineering management and software development, increased employer support for advanced training, and a practice-oriented master's degree in engineering.

Box 5-4: A "Value-Added PhD"

Maintaining Excellence in Research. We are not recommending that all students be prepared for nonresearch careers. Opportunities appear to be growing in nonresearch jobs now;

but we will continue to need many of the best students to dedicate themselves to research in academic and nonacademic settings, and they will need the depth and quality of graduate experience that basic researchers have long enjoyed.

Furthermore, we are not espousing what some call vocationalism. The idea is not to slot every student into a particular career path and then "train" him or her accordingly. Among other problems, that would bind students to jobs that can change or decline in number while they are in graduate school. What is needed is not additional specialization. We need a graduate system that is well tuned to the central feature of contemporary life: continuous change. Change is happening both within the research world and outside, and work in both spheres requires constant readiness to adapt. Our objective, therefore, is a breadth of experience so that graduates can keep career options open and have the capacity to switch career tracks both at the beginning of and throughout their professional lives.

Controlling Time to Degree. The recommended changes should not be construed as additional requirements that would in themselves extend a student's time in a graduate program. The steadily lengthening time to degree—and, more important, the time to first employment—is already too long, for whatever reasons. Many ways of fostering versatility, including several noted above, can easily be introduced within the time that graduate students now spend after registration. An industrial assignment, for example, might replace—and not supplement—an on-campus research assignment.

We are aware of some strain between broadening the graduate experience and controlling its duration. Both solutions are needed, even if considerable administrative energies are required. Although long average time to degree is often decried, faculty and administrators have not generally made the disciplined effort that is needed to tighten graduate programs.

Whatever the nature of a specific graduate program, it is crucial to establish the principle that each student is the responsibility of a department, not of a single faculty member. Thus, a small faculty group (including the adviser) should meet often with each student working for a PhD degree; this faculty group, not the student's faculty adviser acting alone, should determine when enough work has been accomplished for the PhD degree.

Some observers have suggested fixed limits—5 years, perhaps, which is about 2 years shorter than the current averages—for a doctoral-education career. In the abstract, it is not obvious why such a period, which would allow 2 years of coursework and 3 years for a dissertation, should not suffice for most full-time PhD candidates. However, we are not prepared to espouse strict limits, in part because today's more-diverse student population requires flexibility to accommodate family and other personal factors.

However, we do believe that the "Two Plus Three Plus X" model for doctoral education ought to be evaluated and debated within the academic community. The idea is that preparation for a career in research has three discrete phases. The first, which should require no more than 2 years (assuming adequate preparation and suitable adjustment for part-time students), is for developing a broad command of the field. The second, for which the norm might be 3 years, is for making an original contribution to research as reflected in the dissertation. The third, for refining research skills and specialized knowledge that might be required for a first research

position, should be left to postdoctoral assignments. Our concern is that the second and third phases are often merged in current practice.

We urge institutions to set their own standards on time to degree. This could be done at the departmental or program level, and it could accommodate the features of individual disciplines and the character of the student body. The standards should be clearly communicated to students and advisers, and responsibility for enforcement should be accepted by university administrators.

Attracting Women and Minority-Group Members. It is essential that a fair share of the best students be attracted to each discipline in science and engineering. If it appears that the numbers of women and minority-group members are low in particular fields, an effort must be made to determine whether there are barriers to entry, including issues perceived as barriers by members of the group in question. If so, steps to encourage increased participation should be devised and implemented.

Paula Hammond, a postdoctoral engineering student at Harvard University and recent PhD graduate of MIT, sees the need to improve the mentorship provided to all graduate students, but especially to women minority-group members. As a black woman, she has also seen how helpful are such opportunities as fellowships, student travel to professional conferences, and undergraduate training programs for minority-group members. Such activities are effective in encouraging careful planning, providing improved access to professors, and "showing minority-group students the ropes."

Box 5-5: Minority Issues: Suggestions for Improvement

5.3 TOWARD BETTER CAREER INFORMATION AND GUIDANCE

The committee is concerned about the lack of organized and timely career information and guidance that is available to students and their advisers—especially about the absence of reliable information on the less-conventional career paths of scientists and engineers.

Faculty attitudes have sometimes favored academic research careers, and some students have come to feel that other career paths were less worthy.

"Our message is a simple one: Everyone who teaches and counsels future scientists and engineers must give careful consideration to the many profound changes in career paths in these fields and in the economy and workforce generally."

Source: Good and Lane, 1994

During their graduate years, students by themselves have access to little more than anecdotal information about career options. Many proceed through these years presuming that research jobs will be available in sufficient numbers to allow them some freedom of choice. They might see no urgency to investigate alternative careers when actual job entry is several years away and few sources of information about such careers are available. Their faculty advisers, having spent most of their time interacting with other academic researchers, might have little personal knowledge about alternatives and thus no basis to advise

students about them. Former students who have taken nonresearch jobs are often less visible to their graduate departments than former students in traditional positions and are too seldom available as career models for current students. Departments generally do not adequately track information on nonacademic nonresearch employment so that it will be available to potential and current students.

The lack of reliable and timely information impedes the adjustments of the supply of graduate scientists and engineers—both upward and downward—to the demands of the job market.

The committee stresses that departments should not assume that the burden of learning about realistic career options rests with students. They have an affirmative obligation both to know what the full range of options is and to impart that knowledge to students.

Graduate students in science and engineering have insufficient current information on careers and employment. Some academic institutions and societies are now offering seminars and other programs on this topic. To judge by attendance, student interest is high.

For example, Stanford University recently held a symposium on education and careers in biomedicine. The symposium was described as "an interactive forum to address the issues that have been generated by the current shortage of academic positions and to identify alternative and traditional career opportunities as well as educational needs for both predoctoral and posidoctoral fellows." Presenters included persons in government, academe, industry, and law.

Similarly, Princeton University recently held a seminar on careers in chemistry. Industry representatives, entrepreneurs, and representatives of professional societies provided an overview of nontraditional careers. The organizers offered information on resume-writing, job-interview skills, and job-search techniques.

Box 5-6: Career Seminars for Graduate Students

5.3.1. Graduate scientists and engineers and their advisers should receive more up-to-date, accurate, and accessible information to make informed decisions about professional careers. Broad electronic access to such information should be provided.

We recommend that a national database on employment options and trends be established. The database information, intended for both students and their advisers, should include, by field, data on career tracks, graduate programs (including financial aid), time to degree, and placement rates.

Given the diversity of the information for which there is a need, it is clear that the responsibility for providing data must be shared by all partners in the graduate-education enterprise, including the universities, federal and state agencies, and professional societies.

The rapid development of information networks—collectively called the Internet—makes it possible to organize employment and career information so that two important principles are maintained: the information made available in the information system retains decentralized "grass roots" and therefore more currency than information previously assembled into central compendia; and timely information is available where it is most needed—in the hands of the

ultimate consumers, doctoral students, graduates, and their mentors and advisers. In the past (for example, as recently as the downturn in aerospace employment in the 1970s), it would not have been possible to construct an employment-information system that recognized those principles. The new technologies can and should be deployed to improve nationwide access to accurate, germane, and timely education and employment information.

The National Science Foundation should coordinate the federal participation needed to organize the database. However, it is preferable that the database be designed and managed within the research community itself so that it has accurate and timely information that is credible to students and other users, some of it collected from university departments and professional societies. A national organization that covers the many fields of science and engineering could be a catalyst in establishing the database.

5.3.2. Academic departments should provide employment information and career advice to prospective and current students in a timely manner and should help students see career choices as a series of branching decisions. Students should be encouraged to consider discrete alternative pathways when they have met their qualifying requirements.

Graduate students typically devote years of intense effort to their education, and they deserve thoughtful, individual advice about career options. Many faculty members find that advising and mentoring are among the most important and most rewarding of their responsibilities. But more can be done to make sure the advice that is given is both pertinent and complete.

Advice for students should not be limited to the personal knowledge of the faculty member who serves as a student's adviser. Departments should both understand and convey the employment prospects of their graduates. One way to start is to track—perhaps with the assistance of alumni affairs offices—their own past graduates systematically.

Use of information in the national database recommended above could help. We hope, in addition, that some of the

To help graduate students to make career choices, some universities provide information on the employment of their graduates. For example, business school at the University of Chicago provides an overview of the placement, salary, and demographics of its graduates by industry, function, geographic region, undergraduate major, years of work experience, and recent employers. This information is distributed to potential and current students and to potential employers.

A few universities provide useful information about science and engineering graduates. Michigan State University indicates the employment sector, geographic distribution, salary trends, and unemployment rate of its science and engineering graduates.

Although some universities collect employment information, they rarely provide it to those attempting to decide whether to enter graduate-degree programs. Doing so could allow students to make better decisions about courses, programs, and, ultimately, careers.

Box 5-7: Employment Information for Students

demonstration effort funded under a program of education/training grants would allow departments to invent and try other novel means of improving the advice that students receive.

In the past, when most students were destined to become professors, graduate school was more accurately construed as a step on a simple career ladder. We are concerned that that perception is still held in some places. Departments should help students to conceive of their time in graduate school as a series of deliberate decision branches.

Academic departments can focus attention on the importance of career choice at two particular points. The first is the application stage. It would be helpful if more departments, in describing their programs to potential students, routinely provided more data relevant to career choice, such as location of job placements, salaries, and unemployment rates for the department and the discipline as a whole. Departments should report on the careers of all their graduates and provide the relevant information to prospective and current students. Such information could help to prevent unrealistic expectations among students.

> Leonard Carter is an older graduate student at Boston University pursuing a PhD in astrophysics. He has extensive work experience in government and for-profit and nonprofit corporations. He believes that the most-effective preparation for a career is a combination of academic studies and working apprenticeships. To this end, he suggested increasing partnerships among industry, academe, and government.
>
> In line with his own experience, he advocates flexible career preparation. Students should be encouraged to do apprentice work in a variety of areas to understand the full range of employment options and the work culture of industry.
>
> He suggests that universities assist in this effort by tracking PhDs, obtaining feedback from them 3-5 years after graduation, and providing this feedback to current students.

Box 5-8: Viewpoint of an Older Student

The second point is the beginning of the research phase, which usually begins with the passage of the qualifying examination for doctoral students. That is when departmental advisers can help students to evaluate each of three distinct options:

- Some might conclude that a master's degree is sufficient, given their aspirations and the current employment demand for PhDs.
- Some might elect to proceed toward a PhD and try for a position in research.
- Students interested in nontraditional careers could design dissertations that meet high standards for originality but require less time than would be customary for a career in academic research.

The last of those options is often neglected. Implementing the first, which is typically undervalued, might require some reshaping of the master's program to ensure that those who switch from the doctoral program receive—and are perceived to receive—something more than a consolation award. Among other advantages, this counseling approach will require that the leading faculty members come to respect the alternative careers that are available to their students.

Professional societies are often in the best position to gather nationwide employment information on scientists and engineers by field. Some—the Graduate Student Packet of the American Physical Society and American Institute of Physics is a good example—have made impressive starts in this direction. University departments should help to communicate their results to students and advisers.

5.3.3. The National Science Foundation and National Research Council should continue to improve the coverage, timeliness, and analysis of data on the education and employment of scientists and engineers to support better national decision-making about human resources in science and technology.

NSF has the responsibility for collecting, analyzing, and disseminating information on the science and engineering enterprise. In addition to the series of biennial reports on science and engineering indicators, NSF publishes a number of more specialized reports on the production and use of scientists and engineers at all degree levels. Through such activities, it holds the lead role in providing policy-related information to national decision-makers in government, industry, academe, and scientific societies. Some of the data collection related to graduate education, including the Survey of Doctorate Recipients, is done by the National Research Council.

Scientific and engineering societies provide helpful career guidance about current trends. This information is often obtained by surveys of the membership and published by the societies.

For example, the American Chemical Society annually offers data on career opportunities, an overview of the current workforce, information on jobs, job-hunting tips, an analysis of help-wanted ads, a salary survey, and sources of information on career planning.

Another example is an excellent document produced by the American Physical Society (APS) and the American Institute of Physics (AIP) for graduate students in physics; entitled Graduate Student Packet (APS, 1995), it provides information on employment statistics, corporations employing the largest numbers of physicists, how to write a resume and cover letter, interview tips, a list of nontraditional positions held by physicists, and a list of resource books, bulletins, and directories. Also included are interesting biographical sketches of people in nontraditional occupations. Besides general biographical information, the persons profiled indicate what careers are like, give career path information, and give general career advice. The document is provided free by APS and AIP to anyone on request.

Society information tends to be more current and specific than information published by the federal government. For graduate students who maintain membership, it offers overviews of the employment market throughout their student careers. Universities can help by disseminating this information to students who are not members.

Box 5-9: Disciplinary Societies and Career Information

In preparing this report, we have been limited in various ways by the lack of timely and relevant information that policy-makers—and students and their advisers—should have. NSF should address the following:

Timeliness. Databases and reports should be made available soon after the data are collected.

Nonacademic employment. NSF should increase the degree of detail of data on nonacademic employment, which now accounts for most new scientists and engineers. More information is also needed on the career tracks followed by scientists and engineers, both inside and outside universities.

Extramural research. In addition to strengthening its own data collection and analysis, NSF should expand its support of extramural research on career patterns in advanced science and engineering.

5.4 TOWARD IMPLEMENTATION OF A NATIONAL POLICY

In preparing our last report, *Science, Technology, and the Federal Government: National Goals for a New Era* (COSEPUP, 1993), it became clear that no coherent national policy guides the education of advanced scientists and engineers, even though the nation depends heavily on them. That recognition was an important stimulus for the present report.

A casual observer might say that federal policy should simply be to fund the best research and that sound graduate education is an automatic byproduct. There is some validity to that view, but we believe that it is time to reconsider the stewardship of our human resources separately. The nation's graduate programs must prepare scientists and engineers for contributions not only to the nation's basic research, but also to a wide array of other national objectives. Simply to let the development of human resources be guided by the workings of the relevant labor markets is an inadequate policy, given the long lead times required to make career decisions.

At present, there is neither the conceptual clarity nor the factual basis for us to lay out a coherent policy. We are concerned that many prevailing views are obsolete or obsolescent.

5.4.1. A searching national discussion that includes representatives of government, universities, employers, and professional organizations should examine the goals, policies, conditions, and unresolved issues pertaining to graduate-level human resources.

Graduate education is the responsibility of private and state-supported universities; of the federal and state governments, which support many students; of the corporate sector, which increasingly employs those who complete it; and of public and private foundations, which

support its conduct and study its workings. All those parties need to be involved in a continuing reconsideration of graduate education and its national purposes.

Three kinds of issues are suggested as worthy of a searching national discussion:

- National goals and policy options.
- System characterization.
- Contemporary issues.

National Goals and Policy Options. How can we judge the overall adequacy of the national system of graduate education in science and engineering? Our 1993 *Goals* report suggested three goals to keep in mind in assessing the nation's performance in research. Goal 1 is for the United States to be among the world leaders in all major fields of research. Goal 2 is for the United States to maintain clear leadership in selected fields. Goal 3 is for the United States to cede technological leadership in no technology because of technical backwardness alone.

Whether that framework suggests a corresponding set of goals for graduate education or whether some other goals are appropriate should be considered. With better agreement on goals, participants could productively refine the roles and responsibilities of each sector—university, state and federal government, professions, corporations—in meeting them.

Policies and goals for graduate education, to be truly national, must be the shared objectives of all—the research and teaching institutions, state leaders, the federal agencies responsible for support of research and education, and Congress. Developing a shared national view of such goals (and not just a federal view) could lead to a series of policies and actions taken by all the partners in the system.

The science and engineering graduate-education enterprise, which serves multiple national objectives, should be measured against several yardsticks. It should ensure a steady supply of precollege and college teachers, of university faculty, and of researchers in academic, government, and industrial laboratories. It should meet the expanding need for advanced scientists and engineers in careers outside research. And it should offer a diverse vision of education and employment that inspires future generations of American students to strive for careers in science and technology.

System Characterization. What are the key trends in graduate education with respect to employment patterns, career paths, financial support from public and private sources, program evolution, and so on? What are the determinants of those trends?

The national discussion could examine whether underemployment is widespread, how nontraditional employers view new PhDs, the growth of postdoctoral positions, and how people choose careers. It could also monitor progress on innovations, such as the measures recommended in this report, and it might thus serve as a clearinghouse for information on university programs intended to foster versatility, including those stemming from demonstrations

funded by education/training grants, and facilitate the development of a national database for better career decision-making.

Contemporary Issues. Finally, the national discussion could examine current issues on which opinions diverge across the sectors, including the difficult issues—time to first job and sources of new students—discussed in Chapter 4.

5.5 CONCLUSION

In conclusion, the committee believes that science and engineering graduate programs will be improved if

- Science and engineering programs are made more flexible and provide more options for students so that they are more versatile.
- Graduate-student support is shifted to education/training grants.
- Time to degree is controlled.
- More women and minority-group members are attracted to them.
- Better and more-timely career information and guidance are provided while diversity and excellence in research are maintained.

How can reforms like this work in a system as decentralized as graduate education? The committee feels that there is one especially good way: for the major participants—universities, government, industry, and foundations—to come together to discuss these issues. Although some major universities have been slow to consider reforms, there has in fact been tremendous innovation, and our specific recommendations for institutional change are being implemented somewhere. This should be better known. The committee feels strongly that having a national dialogue could strengthen an educational process that must change at least as fast as the world around it.

A

Biographical Information on Committee Members

Phillip A. Griffiths (Chair) is the director of the Institute for Advanced Study in Princeton, New Jersey. He has been professor of mathematics at Princeton University and Harvard, and provost and James B. Duke Professor of mathematics at Duke University. He earned his BS at Wake Forest University and his PhD at Princeton University in 1962. He is a member of the National Academy of Sciences. His current research centers on the geometry of differential equations.

Robert McCormick Adams is secretary emeritus of the Smithsonian Institution in Washington, D.C. and adjunct professor of anthropology at the University of California, San Diego. He is a member of the National Academy of Sciences (NAS) and has been a councilor of the NAS twice. From 1955 to 1984 he was a member of the University of Chicago faculty. He earned a PhB in 1947, an AM in 1952, and a PhD in 1956, all at the University of Chicago.

Bruce M. Alberts is president of the National Academy of Sciences (NAS) and is a biochemist who has been recognized for his work in both biochemistry and molecular biology. He graduated from Harvard College with a BS and earned a PhD in 1965 at Harvard. Dr. Alberts has long been committed to the improvement of science education and serves on the advisory board of the NAS's National Committee on Science Education Standards and Assessment.

Arden L. Bement is Basil S. Turner Distinguished Professor of Engineering and director of the Midwest Superconductivity Consortium at Purdue University. He was vice president for science and technology at TRW, Inc. He earned a professional degree of Metallurgical Engineer (EMet) at the Colorado School of Mines, a MS at the University of Idaho, and a PhD from the University of Michigan. He is a member of the National Academy of Engineering and a recipient of the Distinguished Civilian Service Medal of the Department of Defense.

Elkan R. Blout is director emeritus of the Division of Biological Sciences at Harvard School of Public Health and Edward S. Harkness Professor of Biological Chemistry, Emeritus, at Harvard Medical School. He earned an AB at Princeton University in 1939 and a PhD in chemistry at Harvard in 1942. He is a member of the National Academy of Sciences and the Institute of Medicine.

Felix E. Browder is university professor of mathematics at Rutgers University and former vice president for research. He is also Max Mason Distinguished Service Professor, Emeritus, of the University of Chicago. He graduated from Massachusetts Institute of Technology with a BS in 1946 and obtained his PhD in mathematics at Princeton University in 1948. His research centers on partial differential equations and nonlinear functional analysis. He is a member of the National Academy of Sciences and was elected to the council of NAS in 1992.

David R. Challoner is vice president for health affairs at the University of Florida and chairman of the board of directors of the Shands Hospital. He earned an MD at Harvard Medical School in 1961 and was dean and professor of medicine at the St. Louis University School of Medicine before taking his post in Florida. His clinical specialty is internal medicine with a subspecialty interest in endocrinology. He is a member of the Institute of Medicine.

Ellis B. Cowling is University Distinguished Professor At-Large and director of the Southern Oxidants Study at North Carolina State University. He earned a BS and an MS at the State University of New York College of Forestry at Syracuse University (wood technology), a PhD at the University of Wisconsin (plant pathology and biochemistry), and Filosofie Licensiat and Filosofie Doktor degrees in physiological botany at the University of Uppsala in Sweden. He is a member of the National Academy of Sciences.

Bernard N. Fields was the Adele Lehman Professor and chairman of the Department of Microbiology and Molecular Genetics at Harvard Medical School. He earned his AB at Brandeis University and a MD in 1962 at New York University School of Medicine. He was a postdoctoral fellow in cell biology at the Albert Einstein College of Medicine and was a member of the Institute of Medicine. He died in 1995.

Alexander H. Flax is a senior fellow at the National Academy of Engineering (NAE). He received his BS in aeronautical engineering from the Guggenheim School of Aeronautics of New York University in 1940 and a PhD in physics from the University of Buffalo. He was president of the Institute for Defense Analyses for 14 years before to coming to NAE. He is a member and former home Secretary of the National Academy of Engineering.

Ralph E. Gomory is president of the Alfred P. Sloan Foundation. He received his BA from Williams College in 1950, studied at Cambridge University, and received his PhD in mathematics from Princeton University in 1954. He was director of research for the IBM Corporation from 1970-1986, and senior vice president for science and technology from 1986-1989. He is a member of both the National Academy of Sciences and National Academy of Engineering. He has been awarded a number of honorary degrees and prizes, including the National Medal of Science.

Thomas D. Larson is a consultant and former administrator of the Federal Highway Administration. He earned his BS, MS, and PhD in civil engineering at Pennsylvania State University. He is a member of the National Academy of Engineering and the National Academy of Public Administration. He served for 8 years as secretary of transportation for Pennsylvania and as a chaired professor at Pennsylvania State University.

Mary Jane Osborn is head of the Microbiology Department at the University of Connecticut Health Center. She received a BA (physiology) from the University of California, Berkeley and a PhD (biochemistry) from the University of Washington. Dr. Osborn is a member of the National Academy of Sciences. Her research focuses on biogenesis of bacterial membranes.

Phillip A. Sharp is Salvador E. Luria Professor in the Center for Cancer Research and head of the Department of Biology at the Massachusetts Institute of Technology. He received a BA (chemistry and mathematics) from Union College, Kentucky, and a PhD (chemistry) from the University of Illinois, Urbana/Champaign. He is a member of both the National Academy of Sciences and the Institute of Medicine and corecipient of the 1993 Nobel Prize in physiology and medicine.

Kenneth Shine is president of the Institute of Medicine and professor of medicine, emeritus at the University of California at Los Angeles School of Medicine. He is the School of Medicine's immediate past dean and provost for medical sciences. Both a cardiologist and a physiologist, he received his AB from Harvard College and his MD from Harvard Medical School.

Ralph Snyderman is chancellor for health affairs and dean of the School of Medicine at Duke University. Formerly, he was senior vice president for medical research and development at Genentech, Inc. and Frederic M. Hanes Professor of Medicine and Immunology at Duke. In 1991, he was awarded the Ciba Geigy award for lifetime achievement in inflammation research and in 1993, he was awarded the Bonazinga Award for Excellence in leukocyte-biology research. He received his BS degree from Washington College and his MD degree from the SUNY Downstate Medical Center. He is a member of the Institute of Medicine.

H. Guyford Stever is trustee at a variety of scientific agencies and a consultant on science issues. He was science and technology adviser to President Ford (1976-1977). From 1972 to 1976, he was director of the National Science Foundation. He was president of Carnegie-Mellon University from 1965 to 1972, chief scientist of the Air Force from 1955 to 1965, and professor of aeronautical engineering at Massachusetts Institute of Technology from 1946 to 1965. He received degrees from Colgate and California Institute of Technology. He is a member of the National Academy of Sciences and the National Academy of Engineering (NAE), serving as the NAE foreign secretary from 1984 to 1988. In 1991, he was awarded the National Medal of Science.

Morris Tanenbaum retired as vice chairman of the board and chief financial officer of AT&T in 1991. He earned a BA in chemistry at Johns Hopkins University and a PhD in physical chemistry at Princeton University. He pioneered the use of silicon as a commercial semiconductor material through the invention of the diffused base silicon transistor and was a leader of the group that discovered the first practical materials for superconductor magnets. He is a member and currently vice president of the National Academy of Engineering.

Robert M. White is president of the National Academy of Engineering. He holds a BA in geology from Harvard University and MS and ScD degrees in meteorology from the Massachusetts Institute of Technology. He served under five US presidents from 1963 to 1977, first as chief of the US Weather Bureau and finally as the first administrator of the National Oceanic and Atmospheric Administration. In those capacities, he brought about a revolution in the US weather warning system with satellite and computer technology, helping to initiate new approaches to the balanced management of the country's coastal zones.

B

Statistics on Graduate Education of Scientists and Engineers

Michael McGeary
Study Director, Committee on Science, Engineering, and Public Policy

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OVERVIEW

About 1,500 institutions of higher learning in the United States have programs leading to degrees in science and engineering. Of those, nearly 300 offer doctoral-degree programs in science and engineering. They also offer master's degrees, and more than 400 nondoctoral academic institutions offer master's-degree programs in science and engineering. In 1992, about 430,000 graduate students were in science and engineering programs; 87% of them were at the 300 doctorate-granting institutions.

In 1992, about 80,000 master's degrees and 25,000 doctoral degrees were earned in science and engineering fields. About one-fourth of the doctorates were awarded in each broad field of science and engineering: physical/mathematical sciences, life sciences, social sciences, and engineering. The median time from the bachelor's degree to the PhD was 9.2 years. More than half of the master's degrees and 90% of the PhDs are awarded by the 150 universities that receive 90% of federal academic R&D funding.

About 5% of all science and engineering doctorate recipients in 1993 (14% of life-sciences PhDs) were supported by federal fellowships and traineeships. Another 61% (including 78% of physical scientists and 69% of engineers) received external support, primarily research assistantships and teaching assistantships. Many of the research assistantships were funded by federal grants. About one-quarter of the science and engineering doctoral recipients (including one-half the social scientists) were self-supporting (including federally guaranteed loans).

More than one-third more doctorates in science and engineering were awarded in 1993 than in 1983. Seven-tenths of the net increase in doctorate awards went to foreign citizens with temporary visas, and most of the remaining increase was to US women. In 1993, nearly 30% of the doctorates were earned by women, up from about 25% in 1983. In 1992, 5.7% of PhDs were earned by members of underrepresented minorities in 1992, up from 4.1% in 1983; most of the increase was earned by Hispanics. Foreign citizens with temporary visas greatly increased their share of US doctorates, earning 18.5% in 1983 and 32% in 1993; almost all the net increase was accounted for by citizens of Asian countries. Nearly half of the engineering PhDs went to foreign citizens with temporary visas.

THE GRADUATE STUDENTS

In 1992, the National Science Foundation (NSF) estimated that about 431,600 students were enrolled in graduate science and engineering degree programs (NSF, 1994a:Table 1). Most (87%) were enrolled in doctorate-granting institutions, a proportion that has varied only slightly since the NSF survey began in 1975. Most (67%) were full-time students (this proportion was 72% in doctorate-granting institutions).

It is not possible to tell which of these graduate students were enrolled in master's degree programs and which in doctoral programs, although many PhD recipients have master's degrees (72% in 1993) (NRC, 1995:Appendix Table A-3).

Table B-1, a comparison of the distribution of science and engineering graduate students among fields by type of institution and enrollment status shows that life-sciences graduate students were somewhat more likely than science and engineering graduate students overall to be at doctorate institutions and to be enrolled full-time. Social sciences and behavioral-science graduate students had the opposite pattern: they were somewhat more likely to be part-time and at master's institutions. Engineering graduate students were slightly more likely to be at doctorate institutions but more likely to be enrolled part-time.

TABLE B-1 **Distribution of Science and Engineering Graduate Students, by Field, 1992**

Field	All Institutions, All Students	Doctorate-Granting Institutions	
		All Students	Full-Time Students
TOTAL	431,613 (100%)	374,781 (100%)	270,984 (100%)
Physical/ mathematical sciences	106,548 (25.0%)	93,429 (25.2%)	69,053 (25.8%)
Astronomy	869	869	840
Physics	14,264	13,734	12,432
Chemistry	19,904	18,799	16,611
Physical sciences n.e.c.	459	209	128
Mathematical sciences	20,375	17,890	13,889
Environmental sciences	15,609	13,964	10,567
Computer sciences	36,396	29,042	15,554
Life sciences	66,046 (15.3%)	61,114 (16.3%)	51,676 (19.1%)
Agricultural sciences	11,609	10,891	8,907
Biological sciences	54,437	50,223	42,769
Social/behavioral sciences	139,644 (32.4%)	110,868 (29.6%)	77,464 (28.6%)
Social sciences	85,824	73,170	50,272
Psychology	53,820	37,698	27,192
Engineering	118,047 (27.3%)	108,292 (28.9%)	71,823 (26.5%)

SOURCE: Calculated from Table 1 in NSF, 1994a.

Non-US Citizens

Nearly 110,000 (25.3%) science and engineering graduate students were not US citizens in 1992. About 93,000 of them were enrolled full-time. Their distribution among fields differed from that of US-citizen science and engineering graduate students. Table B-2 shows the distribution of full-time science and engineering graduate students by citizenship and broad field in 1992. Those who were not US citizens were more likely to be studying engineering or the physical sciences and less likely to be in life-science or social/behavioral-sciences programs.

As a result, those who were not US citizens constituted relatively high proportions in some fields—46% of all full-time graduate students in engineering and 39% of those in the physical/mathematic sciences—but low proportions in other fields—27% of all full-time graduate students in the life sciences and 17% of those in the social/behavioral sciences or psychology.

TABLE B-2 **Distribution of US and Non-US Citizens, by Broad Field, 1992**

Field	Full-Time Science and Engineering Graduate Student, All Institutions	
	US Citizen	Non-US Citizen
TOTAL	198,198 (100.0%)	92,795 (100.0%)
Physical/ mathematical sciences	45,177 (22.8%)	28,983 (31.2%)
Life sciences	39,146 (19.7%)	14,652 (15.8%)
Social/behavioral sciences	73,661 (37.2%)	14,908 (16.1%)
Engineering	40,214 (20.3%)	34,252 (36.9%)

SOURCE: Calculated from Tables 13 and 14 in NSF, 1994a.

Female Graduate Students

In 1992, more than 150,000 (35%) science and engineering graduate students were women (up from 25% in 1977). As Table B-3 shows, they were more likely to be enrolled in the life sciences or the social/behavioral sciences and less likely to be in the physical sciences or engineering. In fact, half of all female science and engineering graduate students were in social sciences and psychology programs.

As a result, the majority (54%) of graduate students in the social/behavioral sciences were women, as were 44% of those in the life sciences. Only 15% of engineering graduate students and 27% of those in the natural (physical, environmental, mathematical, and computer) sciences were female.

TABLE B-3 **Female Science and Engineering Graduate Students, by Broad Field, 1992**

Field	Number	Percentage Distribution Across Fields	Percentage of All Graduate Students
TOTAL	150,411	100.0	34.8
Physical/ mathematical sciences	28,719	19.1	26.6
Life sciences	29,223	19.4	44.2
Social/behavioral sciences	75,311	50.1	53.9
Engineering	17,158	11.4	14.5

SOURCE: Calculated from Table 8 in NSF, 1994a.

Members of Underrepresented Minorities

Fewer than 29,000 (9%) of science and engineering graduate students who were US citizens were members of underrepresented minorities—black, Hispanic, or American Indian. Compared with all US-citizen graduate students, they were much more likely to be studying social/behavioral sciences (53 versus 37%) and substantially less likely to be in the life sciences (13% versus 20%). Members of underrepresented minorities constituted 13% of US citizens in the social/behavioral sciences and about 7% of those in the other broad fields (see Table B-4).

TABLE B-4 **Members of Underrepresented Minorities, by Broad Field, 1992**

Field	Number	Percentage Distribution Across Fields	Percentage of All US-Citizen Graduate Students
TOTAL	28,866	100.0%	9.0
Physical/math sciences	4,917	17.0%	6.7
Life sciences	3,615	12.5%	7.2
Social/behavioral sciences	15,335	53.1%	12.6
Engineering	4,999	17.3%	6.5

SOURCE: Calculated from Table 2 in NSF, 1994a.

Growth Trends in Full-Time Graduate Enrollment Since 1982

In 1992, there were nearly 291,000 full-time science and engineering graduate students, 30.6% more than in 1982. The growth by field is presented in the first column of Table B-5. Much of the net growth came from foreign citizens; as overall enrollment was increasing by almost 2% a year, foreign enrollment was growing by more than 5% a year (NSB, 1993:50). The second and third columns of Table B-5 compare the increases in full-time science and engineering graduate students who were foreign citizens with those who were US citizens in 1982-1992, by field.

Enrollment increases were also driven by the increased participation of women—3% a year, compared with 1% among men, during the 1980s. There were absolute decreases in the number of male graduate students in the life, environmental, and social sciences and psychology (NSB, 1993:53).

TABLE B-5 **Increases in Full-Time Graduate Enrollment, by Field and Citizenship, 1982-1992 (percentages)**

Field	Citizenship		
	All	Non-US	US
TOTAL	+30.6	+68.1	+18.4
Physical/			
mathematical sciences	+33.7	+90.6	+12.2
Physical sciences	+27.8	+83.9	+7.1
Mathematical sciences	+35.5	+47.8	+28.6
Environmental sciences	-2.5	+63.3	-13.6
Computer sciences	+92.1	+170.3	+50.4
Life sciences	+14.8	+97.6	-0.8
Agricultural sciences	-6.2	+17.3	-14.1
Biological sciences	+20.4	+136.3	+2.3
Social/behavioral sciences	+26.2	+32.4	+25.1
Social sciences	+22.1	+30.1	+19.8
Psychology	+33.2	+53.9	+32.3
Engineering	+48.2	+60.6	+39.6

SOURCES: Calculated from Tables 13 and 14 in NSF, 1994a for 1992; Table B-5 in NSF, 1993a for 1982.

Growth in First-Year and Beyond-First-Year Enrollments, 1982-1992

The NSF survey of graduate students and postdoctorates in science and engineering fields began to collect information on the number of first-year full-time enrollments in 1982. The data indicate that first-year enrollments increased at a lower rate than total full-time enrollments until about 1989, after which they increased more rapidly for several years. During 1982-1992, first-year enrollments increased by 17% and beyond-first-year enrollments by 37% (Table B-6). It is difficult to interpret those data. Are the recent large increases in first-year enrollments the result of reports in the middle to late 1980s of impending shortfalls in the number of PhDs or the tendency of more college graduates to go to graduate school when economic conditions are poor? Also, how much of the higher rate of growth among beyond-first-year graduate students until recently was simply the manifestation of the steadily increasing degree requirements among science and engineering PhDs, and how much was due to graduate students' deliberately delaying completion of their degrees as short-term responses to poor job-market prospects?

TABLE B-6 **Trends in First-Year and Beyond-First-Year Full-Time Enrollments in Doctorate-Granting Institutions, 1982-1992**

Year	First Year	Beyond First Year
1982	70,351	152,419
1983	72,152 (2.6%)	157,786 (3.5%)
1984	70,604 (-1.8%)	160,986 (2.0%)
1985	71,395 (1.1%)	163,100 (1.3%)
1986	73,167 (2.5%)	169,941 (4.2%)
1987	71,255 (-2.6%)	176,265 (3.7%)
1988	70,930 (-0.5%)	180,036 (2.1%)
1989	74,478 (5.0%)	182,677 (1.5%)
1990	76,405 (2.6%)	189,355 (3.7%)
1991	81,140 (6.2%)	196,211 (3.6%)
1992	82,481 (1.7%)	208,512 (6.3%)

SOURCES: Calculated from Tables B-34 and B-35 in NSF, 1992a for 1982; Tables B-24 and B-25 in NSF, 1993a for 1983-1994; unpublished NSF Tables for 1985-1992.

Sources and Mechanisms of Financial Support

In 1992, science and engineering graduate students were supported in a number of ways by a variety of sources. For each full-time student, the NSF survey asks for the "major" (i.e., largest) source of support (e.g., federal, institutional, and self) and the type (e.g., fellowship, and/or research assistantship). Table B-7 shows that the sources of support vary considerably from field to field. Although on the average 20% of full-time science and engineering graduate students received their major support from a federal source, this was the largest source of support for 32% of graduate students in biology and nearly 36% of graduate students in the physical sciences. Only 7% of graduate students in the social or behavioral sciences and 10% of those in the mathematical sciences were supported primarily by federal funds. Nearly two-thirds of mathematical scientists and half of those in the physical sciences received their major support from their institutions (mostly in the form of research and teaching assistantships), but institutional funds were also an important source of graduate support in the other disciplines—between 32 and 45%. "Own funds" (including, however, federally guaranteed loans) were the major source of support for large fractions of graduate students in some fields—46% of those in computer science and 40% of those in the social and behavioral sciences—but for relatively few in physics, astronomy, and chemistry (6%) or the biological sciences (13%). Only a few percent received foreign support (although those completing the

survey might not always have known whether those funding their own way—thus classified as self-supporting—were receiving foreign support). Finally, about 7% overall were receiving support from industry and domestic sources other than federal and institutional. About 11% of students in engineering and agricultural science were receiving such support.

TABLE B-7 **Sources of Major Support for Full-Time Science and Engineering Graduate Students in All Institutions, by Field, 1992**

Field	Total No.	Federal	Institu-tional	Other US	Foreign	Self
TOTAL	290,993	20.0%	41.3%	6.9%	2.1%	29.7%
Physical/ mathematical sciences	74,160	25.0%	47.0%	5.8%	1.6%	20.6%
Physical sciences	30,730	35.7%	50.0%	7.0%	1.1%	6.4%
Mathematical sciences	14,663	10.2%	65.1%	2.4%	2.0%	20.3%
Environmental sciences	11,150	30.9%	39.2%	7.1%	2.2%	20.6%
Computer sciences	17,617	15.0%	31.7%	5.9%	1.8%	45.6%
Life sciences	53,798	31.8%	43.4%	7.9%	2.3%	14.5%
Agricultural sciences	9,280	21.1%	38.7%	11.5%	6.2%	22.5%
Biological sciences	44,518	34.0%	44.4%	7.2%	1.5%	12.9%
Social/behavioral sciences	88,569	7.0%	42.0%	3.5%	1.7%	45.7%
Social sciences	54,183	6.3%	45.0%	3.7%	2.7%	42.3%
Psychology	34,386	8.1%	37.4%	3.2%	0.2%	51.1%
Engineering	74,466	22.1%	33.3%	11.4%	2.7%	30.5%

SOURCE: Calculated from Table 11 in NSF, 1994a.

The pattern of sources of support has not changed much over the last 10 years, as seen in Table B-8; federal, institutional, and other US sources of support were up by several percentage points each, offsetting relative declines in foreign and own sources of support.

TABLE B-8 **Sources of Major Support for Full-Time Science and Engineering Graduate Students, 1982 and 1992**

Year	Total No.	Federal	Institu-tional	Other US	Foreign	Self
1982	208,954	19.3%	41.5%	6.6%	4.0%	28.6%
1992	290,993	20.0%	41.3%	6.9%	2.1%	29.7%

SOURCES: Calculated from Table C-18 in NSFa, 1992 for 1982; and Table 11 in NSF, 1994a for 1992.

The sources of *federal* support for full-time science and engineering graduate students also varied by field (see Table B-9), although the pattern has not changed since 1982 (compare NSF, 1992: Table C-18).

National Institutes of Health (NIH) NIH is the primary source of support for nearly 70% of federally supported graduate students in the biological sciences and also accounts for one-third (34%) of federally funded graduate students in psychology. Overall, NIH is the major source of support for more than one-fourth of the federally supported science and engineering graduate students. Other Health and Human Services (DHHS) agencies pick up a few percent more.

United States Department of Agriculture (USDA) The majority (55%) of federally supported agricultural-science students are funded by USDA. USDA is the primary supporter of few other graduate students (a little more than 5% of federally funded students).

Department of Defense (DoD) Nearly half (45%) of those with major federal support in the computer sciences and more than one-fourth of those in the mathematical sciences are funded by DoD. Overall, DoD is the major source of support for 15% of federally funded graduate students.

National Science Foundation (NSF) Almost one-third of the graduate students in physical sciences who receive their major support from federal sources are funded by NSF. Overall, NSF supports more than a one-fifth of the federally funded graduate students.

Other Other federal agencies are the major source of support for 29% of federally supported graduate students, especially in the social (44%) and environmental (44%) sciences. The only fields that do not receive much support from other federal agencies are the biological (8%) and the computer (14%) sciences.

TABLE B-9 **Federal Sources of Support for Full-Time Science and Engineering Graduate Students in All Institutions, by Field and Agency, 1992**

Field	Total No.	DoD	NIH	Other HHS	NSF	USDA	Federal Sources
TOTAL	58,309	15.0%	25.6%	2.2%	22.7%	5.4%	29.1%
Physical/ mathematical sciences	18,539	17.5%	12.1%	0.8%	34.2%	1.0%	34.4%
Physical sciences	10,956	10.8%	18.6%	1.2%	32.9%	0.6%	35.9%
Mathematical sciences	1,499	25.8%	4.1%	0.5%	30.5%	1.7%	37.6%
Environmental sciences	3,449	13.7%	1.2%	0.2%	38.4%	2.6%	43.9%
Computer sciences	2,635	45.3%	3.7%	0.2%	36.3%	0.2%	14.3%
Life sciences	17,102	1.5%	61.9%	2.8%	8.3%	12.8%	12.7%
Agricultural sciences	1,961	0.9%	1.5%	0.1%	4.3%	55.0%	38.2%
Biological sciences	15,141	1.5%	69.8%	3.1%	8.8%	7.3%	9.4%
Social/behavioral sciences	6,193	5.9%	19.9%	9.1%	14.7%	6.7%	43.8%
Social sciences	3,408	6.7%	8.6%	3.6%	18.3%	11.6%	51.1%
Psychology	2,785	4.8%	33.7%	15.7%	10.2%	0.7%	34.9%
Engineering	16,475	29.7%	5.2%	0.6%	27.7%	2.2%	34.6%

SOURCE: Calculated from Table 11 in NSF, 1994a.

As for the *mechanisms* of support (including nonfederal), the latest detailed data by field are for 1991 (Table B-10).

Fellowships Fellowships are awarded to individual graduate students on the basis of merit. Table B-10 shows that about 10% of the 259,000 full-time science and engineering graduate students were supported by fellowships in 1991, and fellowship support was spread fairly evenly across the disciplines (about one-fourth of the fellowships were federally funded).

Traineeships Traineeship programs are competitively awarded to universities, which select the graduate students to support. About 4% of science and engineering graduate students were trainees, most of them in the biological sciences. (About 60% of the trainees were federally supported; 30% were institutionally funded.)

Research Assistantships About 30% of full-time science and engineering graduate students were supported as research associates on research grants awarded to faculty supervisors. The proportion varied by field. Graduate students in the some of the physical sciences and the life sciences were more likely to be research associates; those in the mathematical sciences and

social and behavioral sciences were less likely. (About half the research assistants were supported by federal funds and one-third by institutional funds.)

Teaching Assistantships More than one-fifth (23%) of graduate students were supported primarily as teaching assistants. Graduate students in mathematics and in the physical sciences were especially likely to be teaching assistants; those in engineering and agricultural sciences were less likely than average to have teaching assistantships.

Other Support "Other support" includes loans, personal funds, and tuition payments by industry and government agencies. It accounts for more than a third (33%) of graduate students. It was especially important in some fields; about half those in computer science, psychology, and social sciences were supported other than by fellowships, traineeships, and research or teaching assistantships. Graduate students in biology or the physical sciences were less likely to rely on other types of support.

TABLE B-10 **Mechanisms of Major Support for Full-Time Science and Engineering Graduate Students in Doctorate-Granting Institutions, 1991**

Field	Total No.	Fellow-ships	Trainee-ships	Research Assistant-ships	Teaching Assistant-ships	Other Types of Support
TOTAL	259,484	9.6%	3.9%	30.4%	23.3%	32.8%
Physical/ mathematical sciences	67,352	8.6%	1.8%	31.0%	36.3%	22.3%
Physical sciences	29,364	9.1%	2.6%	41.0%	38.9%	8.4%
Mathematical sciences	13,525	9.9%	1.6%	9.4%	55.2%	23.9%
Environmental sciences	9,880	9.1%	0.9%	42.5%	22.9%	24.5%
Computer sciences	14,583	5.8%	0.8%	23.3%	22.6%	47.5%
Life sciences	50,075	10.3%	10.3%	42.6%	18.1%	18.6%
Agricultural sciences	8,793	4.9%	0.9%	55.4%	9.0%	29.9%
Biological sciences	41,282	11.5%	12.3%	39.9%	20.1%	16.2%
Social/behavioral sciences	73,132	11.3%	3.8%	14.0%	21.9%	49.0%
Social sciences	47,080	14.0%	3.4%	13.5%	22.7%	46.3%
Psychology	26,052	6.4%	4.4%	14.8%	20.5%	53.8%
Engineering	68,925	8.1%	1.6%	38.4%	15.9%	36.0%

SOURCE: Calculated from Tables C-19 and C-20 in NSF, 1993a.

Science and Engineering Graduate Students in Master's-Granting Institutions

In 1992, nearly 57,000 science and engineering graduate students were in institutions whose highest degree is the master's. Most of them (65%) were enrolled part-time. Table B-11 gives their distribution and enrollment status by field and compares them with graduate students at doctorate-granting institutions. The table indicates that graduate students in master's degree institutions were much more likely to be in the social sciences and psychology and much less likely to be in the life sciences. In fact, 26% of all graduate students in the social sciences and psychology were in master's-degree institutions, compared with 11% of the remaining science and engineering graduate students.

TABLE B-11 **Science and Engineering Graduate Students in Master's Degree Institutions and Doctorate Institutions, by Enrollment Status and Field, 1992**

	Master's-Granting Institution		Doctorate-Granting Institution	
Field	All Students	Full-Time	All Students	Full-Time
TOTAL	56,832	20,009	374,781	270,984
Physical/ mathematical sciences	13,369 (24%)	4,139 (21%)	94,507 (25%)	70,021 (26%)
Physical sciences	1,885	719	33,611	30,011
Mathematical sciences	2,485	774	17,890	13,889
Environmental sciences	1,645	583	13,964	10,567
Computer sciences	7,354	2,063	29,042	15,554
Life sciences	4,932 (9%)	2,122 (11%)	61,114 (16%)	51,676 (19%)
Agricultural sciences	718	373	10,891	8,907
Biological sci	4,214	1,749	50,223	42,769
Social/behavioral sciences	28,776 (51%)	11,105 (56%)	110,868 (30%)	77,464 (29%)
Social sciences	12,654	3,911	73,170	50,272
Psychology	16,122	7,194	37,698	27,192
Engineering	9,755 (17%)	2,643 (13%)	108,292 (29%)	71,823 (27%)

SOURCE: Calculated from Tables 20 and 21 in NSF, 1994a.

THE INSTITUTIONS

In 1991, there were 3,611 institutions of higher education in the United States; they enrolled 14 million students and granted 1.9 million degrees, of which about one-fourth (470,000) were in science and engineering fields (NSB, 1993:38). The Carnegie Foundation for the Advancement of Teaching has classified those institutions into categories according to the size of their bachelor's-degree and graduate programs, amount of research funding, and—for liberal-arts colleges—selectivity of admissions. Table B-12 shows how many institutions were in each category in 1991.

TABLE B-12 **Number of Academic Institutions with Science and Engineering Programs, by Highest Degree Level, 1991**

Carnegie Foundation Category	Science and Engineering Program		
	Bachelor's	Master's	Doctorate
TOTAL	1,448	738	299
Research I	67	68	71
Research II	34	34	34
Doctorate-Granting I	46	48	48
Doctorate-Granting II	56	57	53
Comprehensive I	419	318	36
Comprehensive II	167	50	1
Liberal Arts I	138	30	4
Liberal Arts II	389	42	0
Two-Year	20	0	0
Specialized	94	69	38
Other	15	20	13
Not classified	3	2	1

SOURCE: Calculated from Appendix Table 2-6 in NSB, 1993.

Although comprehensive and liberal-arts institutions were the majority of institutions granting science and engineering bachelor's and master's degrees, the research and doctorate institutions accounted for large fractions of the degrees granted: 54% of all science and engineering bachelor's degrees and 53% of the master's degrees. Degree production is especially concentrated at the doctoral level (see Table B-13): nearly two-thirds of the science and engineering PhDs awarded in 1991 came from the 71 Research I universities, four-fifths from the 105 Research I and II universities; and nine-tenths from the 153 Research I and II and Doctorate I universities. The same set of 153 universities also receives 90% of all academic R&D funding (NSB, 1993:40; Appendix Table 2-5).

TABLE B-13 **Concentration of Science and Engineering Degree Awards by Type of Institution, 1991**

Carnegie Foundation Category	Total No. and Cumulative Percentage of Science and Engineering Degrees Awarded		
	Bachelors	Masters	Doctorate
TOTAL	337,675	78,368	23,979
Research I	29.3	37.6	65.2
Research II	39.1	49.2	79.5
Doctorate-Granting I	47.2	59.0	89.4
Doctorate-Granting II	53.7	68.0	94.7
Comprehensive I	83.5	91.4	96.2
Comprehensive II	87.0	93.2	96.2
Liberal Arts I	93.6	94.3	96.4
Liberal Arts II	97.7	95.3	96.4
Two-Year	97.9	95.3	96.4
Specialized	99.3	98.1	98.4
Other	99.9	99.9	99.9
Not classified	100.0	100.0	100.0

SOURCE: Calculated from Appendix Table 2-6 in NSB, 1993.

The 105 Research I and II universities produce nearly 80% of the science and engineering doctorates awarded each year (see Table B-14). This concentration of PhD production differs some by broad field, although the 71 Research I institutions accounted for at least the majority of PhDs granted in each.

TABLE B-14 **Concentration of 80 Percent of Science and Engineering PhD Production in the 105 Research Universities, by Field, 1991**

Carnegie Foundation Category	Natural Sciences	Math & Computer Sciences	Social & Behavioral Sciences	Engineering
TOTAL	10,152	1,837	6,778	5,212
Research I (n=71)	67.3%	70.3%	55.4%	71.9%
Research II (n=34)	81.9%	84.5%	71.0%	84.2%

SOURCE: Calculated from Appendix Table 2-5 in NSB, 1993.

There was substantial growth in the number of institutions with graduate degree programs since 1961 (see Table B-15). The number of institutions granting doctorates doubled between 1961 and 1991; the number of master's-degree institutions more than doubled.

TABLE B-15 **Number of Institutions by Highest Degree Level Since 1961, by Decade**

Year	Highest Degree Granted	
	Master's	Doctorate
1961	189	153
1971	287	229
1981	361	293
1991	442	299

SOURCE: Calculated from Appendix Table 5-1 in NSB, 1985 for 1961-1981; and Appendix Table 2-6 in NSB, 1993 for 1991.

SCIENCE AND ENGINEERING MASTER'S DEGREES

Master's Degrees in Science and Engineering

The number of master's degrees awarded in science and engineering has grown every year since 1966 except in the 1979-1981 period (Table 1 in NSF, 1994b). In 1991, over 78,000 science and engineering master's degrees were awarded, up from 41,000 in 1966. Science and engineering master's degrees were 29% of all master's degrees awarded in 1966, a percentage that declined to less than 21 in 1976, increased to 25% in 1987, and fell again to 23% in 1991.

According to Table B-16, about one-third of science and engineering master's degrees are awarded in the social and behavioral sciences, three-tenths in engineering, one-fourth in the natural sciences, and one-tenth in the life sciences (NSF, 1994b). (Compared with 1966, the social/behavioral sciences increased their share by almost 9 percentage points, gaining 5 points from the life sciences, 3 from engineering, and 1 from the natural sciences.)

TABLE B-16 **Science and Engineering Master's Degrees Awarded, by Field, 1966-1991**

Field	1966	1971	1976	1981	1986	1991
TOTAL	41,059 (100.0%)	56,454	65,007	64,366	71,831	78,368 (100.0%)
Physical/ mathematical sciences	9,975 (24.3%)	13,131	11,927	12,029	17,124	18,232 (23.3%)
Physical sciences	4,275	5,115	3,880	3,366	3,649	3,777
Mathematical/ computer sciences	5,010	6,789	6,466	6,787	11,241	12,956
Environmental sciences	690	1,227	1,581	1,876	2,234	1,499
Life sciences	5,865 (14.3%)	7,604	9,223	9,107	8,027	7,406 (9.5%)
Agricultural sciences	1,641	1,848	2,602	3,092	2,983	2,600
Biological sciences	4,224	5,756	6,621	6,015	5,044	4,806
Social/behavioral sciences	11,514 (28.0%)	19,352	27,812	26,779	25,584	28,717 (36.6%)
Social sciences	9,091	14,914	19,953	18,740	17,221	18,915
Psychology	2,423	4,438	7,859	8,039	8,363	9,802
Engineering	13,705 (33.4%)	16,367	16,045	16,451	21,096	24,013 (30.6%)

SOURCE: Calculated from Table 1 in NSF, 1994b.

Women

Women earned 13.3% of the science and engineering master's degrees in 1966, a percentage that increased steadily to nearly 36% in 1991 (see Table B-17). This varied by field.

The number of science and engineering master's degrees per 1,000 24-year-old women in the US population increased from 4 in 1966 to 15 in 1991 (NSF, 1994b:Table 57). Meanwhile, the number going to men went from more than 30 per 1000 in 1969-1970 to 26 in 1991 (after reaching a high of 32 in 1970 and a low of 21 in the early 1980s). Overall, in 1991, 21 master's degrees in science and engineering were awarded for every 1000 24-year-olds in the US population, up from 15 in 1966.

TABLE B-17 **Women as Percentage of Science and Engineering Master's-Degree Recipients, by Field, 1991**

Field	1966	1971	1976	1981	1986	1991
TOTAL	13.3	18.3	23.1	29.3	32.3	35.6
Physical/ mathematical sciences	15.5	19.3	21.1	24.3	29.0	31.3
Physical sciences	11.4	14.4	15.6	20.1	25.0	28.4
Math/computer sciences	20.3	24.9	26.1	27.2	31.4	32.8
Environmental sciences	6.1	9.5	13.9	21.6	23.1	25.6
Life sciences	20.8	27.1	26.8	33.4	41.7	46.3
Agricultural sciences	4.4	6.2	14.1	22.8	31.2	36.2
Biological sciences	27.2	33.8	31.8	38.9	47.9	51.8
Social/behavioral sciences	22.8	28.7	34.0	43.2	48.9	53.7
Social sciences	20.2	26.2	29.0	36.8	41.2	45.6
Psychology	32.9	37.2	46.7	58.1	64.9	69.5
Engineering	0.6	1.1	3.5	8.1	11.4	14.0

SOURCE: Calculated from Table 18 in NSF, 1994b.

Underrepresented Minorities

NSF has collected information on the race, ethnicity, and citizenship of master's degree recipients biennially since 1977. Table B-18 shows that the proportion of science and engineering master's degrees awarded to members of underrepresented minorities (i.e., blacks, Hispanics, and American Indians) has increased slowly in the natural sciences and engineering, offset by declines in psychology and the social sciences, fields that traditionally have registered the largest shares of underrepresented minorities.

TABLE B-18 **Members of Underrepresented Minorities as Percentage of Science and Engineering Master's Degree Recipients, by Field, 1977-1991**

Field	1977	1981	1987	1991
TOTAL	7.8	7.5	7.0	7.3
Physical/ mathematical sciences	4.1	3.7	4.0	4.4
Physical/ environmental sciences	3.4	3.6	3.7	3.4
Mathematical/ computer sciences	5.1	4.5	4.1	5.3
Life sciences	4.2	4.4	5.4	5.3
Agricultural sciences	3.5	3.9	4.2	4.1
Biological sciences	4.6	4.8	6.1	6.0
Social/ behavioral sciences	11.3	11.1	10.2	11.1
Social sciences	11.6	11.7	10.8	11.7
Psychology	10.3	8.4	8.4	9.1
Engineering	3.2	3.4	4.5	3.9

SOURCE: Calculated from Table 4 in NSF, 1994c.

Non-US Citizens

Non-US citizens with temporary visas received almost 20% of the science and engineering master's degrees in 1991, almost double their share in 1977 (see Table B-19). Most

were in physical or mathematical science and engineering programs, where they constituted about 30% of all master's-degree students. They were relatively unlikely to be in social-science or psychology programs.

TABLE B-19 **Science and Engineering Master's Degrees Earned by Students Who Were Not US Citizens, by Field, 1977, 1985, and 1991**

Field	1977 No.	1977 %	1985 No.	1985 %	1991 No.	1991 %
TOTAL	8,282	9.9	13,256	16.3	18,013	19.5
Physical/ mathematical sciences	1,392	11.8	3,492	22.1	5,382	29.5
Physical/ environmental sciences	656	12.3	1,098	18.9	1,504	28.5
Mathematical/ computer sciences	736	11.3	2,394	24.0	3,878	29.9
Life sciences	1,141	10.5	1,080	13.1	1,352	18.2
Agricultural sciences	664	17.8	606	19.2	603	23.0
Biological sciences	477	6.7	474	9.3	749	15.6
Social/ behavioral sciences	2,204	5.0	2,866	8.0	3,583	8.7
Social sciences	2,033	5.6	2,570	9.5	3,270	10.3
Psychology	171	2.1	296	3.5	317	3.2
Engineering	3,545	21.8	5,818	26.7	7,692	30.5

SOURCE: Calculated from Table 4 in NSF, 1994g.

SCIENCE AND ENGINEERING DOCTORAL DEGREES

Doctorates in Science and Engineering

The number of science and engineering PhDs awarded annually tripled between 1958 and 1968 to about 18,000. Between 1968 and 1974, the number leveled off or fell in various fields, although the aggregate number peaked in 1971-1973 at nearly 19,400 per year, and fell to fewer than 18,000 per year by 1977, where it remained through 1981. Table B-20 shows the numbers of science and engineering PhDs awarded during 1983-1993 period.

TABLE B-20 **Science and Engineering Doctorates Awarded, by Field, 1983-1993**

Field	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
TOTAL	18,393	18,514	18,713	19,253	19,710	20,748	21,534	22,688	23,787	24,454	25,184
Physical/ mathematical sciences	4,426	4,452	4,531	4,807	5,030	5,309	5,455	5,859	6,279	6,502	6,496
Physics/Astronomy	1,043	1,080	1,080	1,187	1,237	1,302	1,274	1,393	1,411	1,537	1,543
Chemistry	1,759	1,765	1,836	1,903	1,975	2,015	1,970	2,100	2,193	2,214	2,139
Mathematics	701	698	688	729	740	749	859	892	1,039	1,058	1,146
Computer/ information sciences	286	295	310	399	450	515	612	705	800	869	878
Environmental sciences	637	614	617	589	628	728	740	769	836	824	790
Life sciences	4,756	4,877	4,904	4,804	4,815	5,127	5,203	5,503	5,719	5,861	6,059
Agricultural sciences	1,015	997	1,111	997	976	1,015	1,088	1,176	1,074	1,063	969
Biological sciences	3,741	3,880	3,793	3,807	3,839	4,112	4,115	4,327	4,645	4,798	5,090
Social/ behavioral sciences	6,430	6,272	6,112	6,266	6,153	6,125	6,333	6,432	6,574	6,652	6,933
Social sciences	3,083	3,015	2,994	3,140	2,980	3,051	3,125	3,150	3,324	3,388	3,514
Psychology	3,347	3,257	3,118	3,126	3,173	3,074	3,208	3,282	3,250	3,264	3,419
Engineering	2,781	2,913	3,166	3,376	3,712	4,187	4,543	4,894	5,215	5,439	5,696

SOURCE: Calculated from Table 1 in NSF, 1994b.

In 1982, the number of science and engineering doctorates awarded annually rose above 18,000 for the first time since 1976. The growth rate was still low—about 2% per year—until 1988, when the increase was more than 5% over 1987. The number increased by around 3% per year from 1988 through 1993. Table B-21 shows the increases from 1988 to 1993 by field.

TABLE B-21 **Increases in Numbers of Science and Engineering Doctorates Awarded, by Field, 1988-1993**

Field	1988	1993	Increase No.	Increase Percentage
TOTAL	20,748	25,184	4,436	21.4%
Physical/ mathematical sciences	5,309	6,496	1,187	22.4
Physics/Astronomy	1,302	1,543	241	18.5
Chemistry	2,015	2,139	124	6.2
Mathematics	749	1,146	397	53.0
Computer sciences	515	878	363	70.5
Environmental sciences	728	790	62	8.5
Life sciences	5,127	6,059	932	18.2
Agricultural sciences	1,015	969	-46	-4.5
Biological sciences	4,112	5,090	978	23.8
Social/behavioral sciences	6,125	6,933	808	13.2
Social sciences	3,051	3,514	463	15.2
Psychology	3,074	3,419	345	11.2
Engineering	4,187	5,696	1,509	36.0

SOURCE: Calculated from Table 1 in NSF, 1994f.

Women

The number of women awarded science and engineering PhDs increased from 4,624 in 1983 to 7,537 in 1993, or 63.0%. As a result, the proportion of PhD awards to women increased from 25.1% in 1983 to 29.9% in 1993. They varied from field to field (see Table B-22).

TABLE B-22 **Women as a Percentage of Science and Engineering Doctorate Recipients, by Field, 1983-1993**

Field	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
TOTAL	25.1	25.4	25.7	26.4	26.6	26.9	27.9	27.8	28.7	28.6	29.9
Physical/ mathematical sciences	13.9	14.8	15.8	16.1	16.5	16.6	18.9	18.3	18.7	19.7	20.7
Physics/Astronomy	7.1	7.3	9.4	9.2	9.7	10.0	9.3	10.8	11.1	12.1	12.6
Chemistry	16.9	18.1	19.7	20.8	20.6	21.2	25.3	24.0	23.6	26.2	27.3
Mathematics	16.1	16.5	15.4	16.6	16.9	16.2	18.0	17.7	19.2	19.4	23.0
Computer sciences	12.6	12.5	10.6	12.0	14.4	10.9	17.6	15.6	14.6	13.8	15.6
Environmental sciences	15.2	17.3	18.0	17.0	18.2	19.9	20.3	19.4	22.1	23.4	20.8
Life sciences	28.7	27.6	28.7	30.2	31.8	33.0	34.0	33.8	34.6	35.2	37.6
Agricultural sciences	13.1	13.3	15.4	17.3	17.5	18.3	21.0	21.0	19.5	21.9	23.5
Biological sciences	33.0	31.3	32.6	33.6	35.4	36.6	37.5	37.3	38.1	38.2	40.3
Social/ behavioral sciences	39.1	40.6	40.8	42.0	42.8	44.5	44.8	45.9	48.7	47.1	49.0
Social sciences	29.8	30.4	31.7	33.0	31.4	34.3	33.2	33.0	36.3	35.6	37.1
Psychology	47.7	50.1	49.4	51.2	53.5	54.7	56.1	58.3	61.4	59.1	61.1
Engineering	4.5	5.2	6.3	6.7	6.5	6.8	8.3	8.5	9.0	9.3	9.1

SOURCE: Calculated from Tables 1 and 2 in NSF, 1994b.

Women earning science and engineering PhDs were concentrated in particular fields. In 1993, nearly half (45%) were in the social and behavioral sciences, and 30% were in the life sciences (see Table B-23). The concentration in social and behavioral sciences was reduced over the previous 10 years, however, as more awards to women were made in the physical and mathematical sciences and engineering. Overall, the shift was 4.5 percentage points (to nearly 18%). The number of women receiving PhDs in the physical and mathematical sciences more than doubled from 1983 to 1993 (from 617 to 1,344). The number in engineering quadrupled (from 124 to 521), but fewer than 7% of women PhDs were in engineering.

TABLE B-23 **Science and Engineering Doctorates Awarded to Women, by Field, 1983 and 1993**

Field	1983 Number	1983 Percentage	1993 Number	1993 Percentage
TOTAL	4,624	100.0	7,537	100.0
Physical/ mathematical sciences	617	13.3	1,344	17.8
Physics/astronomy	74	1.6	194	2.6
Chemistry	297	6.4	585	7.8
Mathematics	113	2.4	264	3.5
Computer sciences	36	0.8	137	1.8
Environmental sciences	97	2.1	164	2.2
Life sciences	1,366	29.5	2,278	30.2
Agricultural sciences	133	2.9	228	3.0
Biological sciences	1,233	26.7	2,050	27.2
Social/behavioral sciences	2,517	54.4	3,394	45.0
Social sciences	920	19.9	1,305	17.3
Psychology	1,597	34.5	2,089	27.7
Engineering	124	2.7	521	6.9

SOURCE: Calculated from Table 2 in NSF, 1994f.

The percentage of science and engineering doctorates awarded to members of underrepresented minorities—American Indians, blacks, and Hispanics—has been very low and has increased slowly (see Table B-24). In fact, the percentage of doctorates received by black citizens declined during the last half of the 1980s.

TABLE B-24 **Members of Underrepresented Minorities as a Percentage of Science and Engineering Doctorate Recipients, by Field, 1983, 1988, and 1993**

Field	1983 No.	1983 Percentage	1988 No.	1988 Percentage	1993 No.	1993 Percentage
All US Citizens	13,403	100.0	13,218	100.0	14,708	100.0
Underrepresented Minorities	547	4.1	628	4.8	843	5.7
American Indian	27	0.2	41	0.3	41	0.3
Black	283	2.1	260	2.0	363	2.5
Hispanic	237	1.8	327	2.5	439	3.0

SOURCE: Calculated from Table 3 in NSF, 1994f.

Non-US Citizens

In 1993, more than 8,000 science and engineering PhDs went to foreign citizens with temporary visas—nearly one-third of all the doctorates awarded by US universities (see Table B-25). Only 18.5% of PhDs awarded in 1983 went to foreign citizen with temporary visas. In 1993, they received just under half of the new doctorates in engineering, up from 42% 10 years earlier. They were awarded more than one-third (36%) of the PhDs in the physical and mathematical sciences and more than one-fourth (28%) of those in the life sciences.

TABLE B-25 **Share of Science and Engineering Doctorates Earned by Students Who Were Not US Citizens, by Field, 1983 and 1993**

	1983 Doctorates Awarded			1993 Doctorates Awarded		
	All	Temporary Visa		All	Temporary Visa	
Field		No.	Percentage		No.	Percentage
TOTAL	18,393	3,400	18.5	25,184	8,087	32.1
Physical/ mathematical sciences	4,426	926	20.9	6,496	2,363	36.4
Physics/astronomy	1,043	256	24.5	1,543	583	37.8
Chemistry	1,759	283	16.1	2,139	674	31.5
Mathematics	701	209	29.8	1,146	517	45.1
Computer sciences	286	72	25.2	878	349	39.7
Environmental sciences	637	106	16.6	790	240	30.4
Life sciences	4,756	629	13.2	6,059	1,694	28.0
Agricultural sciences	1,015	307	30.2	969	448	46.2
Biological sciences	3,741	322	8.6	5,090	1,246	24.5
Social/ behavioral sciences	6,430	675	10.5	6,933	1,247	18.0
Social sciences	3,083	596	19.3	3,514	1,099	31.3
Psychology	3,347	79	2.4	3,419	148	4.3
Engineering	2,781	1,170	42.1	5,696	2,783	48.9

SOURCE: Calculated from Table 4 in NSF, 1994f.

The number of non-US citizens with temporary visas increased 138% over a decade—from 3,400 in 1983 to 8,087 in 1993 (Table B-26). That increase was greater in the physical and mathematical sciences and in the life sciences. The rate of growth was lower than average in the social and behavioral sciences.

TABLE B-26 **Increase in Science and Engineering Doctorates Awarded to Non-US Citizens with Temporary Visas, by Field, 1983 and 1993**

Field	1983	1993	Difference No.	Difference Percentage
TOTAL	3,400	8,087	4,687	137.9
Physical/ mathematical sciences	926	2,363	1,437	155.2
Physics/astronomy	256	583	327	127.7
Chemistry	283	674	391	138.2
Mathematics	209	517	308	147.4
Computer sciences	72	349	277	384.7
Environmental sciences	106	240	134	126.4
Life sciences	629	1,694	1,065	169.3
Agricultural sciences	307	448	141	45.9
Biological sciences	322	1,246	924	287.0
Social/ behavioral sciences	675	1,247	572	84.7
Social sciences	596	1,099	503	84.4
Psychology	79	148	69	87.3
Engineering	1,170	2,783	1,613	137.9

SOURCE: Calculated from Table 4 in NSF, 1994f.

Table B-27 shows the distribution of foreign citizens with temporary visas, by field. In 1993, roughly one-third were in engineering, and another one-third were in the physical/mathematical sciences. Around 15-20% were in each of the life sciences and the social sciences. Compared with 1983, temporary-visa holders moved away from the social sciences (by about 4.5 percentage points) and into the physical/mathematical sciences (by about 2 points) and the life sciences (by about 2.5 points).

TABLE B-27 **Science and Engineering Doctorates Awarded to Non-US Citizens with Temporary Visas, by Field, 1983 and 1993**

Field	1983	1993
TOTAL	3,400	8,087
Physical/mathematical sciences	27.2%	29.2%
Physics/astronomy	7.5%	7.2%
Chemistry	8.3%	8.3%
Mathematics	6.1%	6.4%
Computer sciences	2.1%	4.3%
Environmental sciences	3.1%	3.0%
Life sciences	18.5%	20.9%
Agricultural sciences	9.0%	5.5%
Biological sciences	9.5%	15.4%
Social/behavioral sciences	19.9%	15.4%
Social sciences	17.5%	13.6%
Psychology	2.3%	1.8%
Engineering	34.4%	34.1%

SOURCE: Calculated from Table 4 in NSF, 1994f.

The country of origin of temporary-visa holders shifted during the 1980s (see Table B-28). Citizens from eastern Asia increased their share of science and engineering PhDs awarded to temporary-visa holders from one-fourth to more than a half. Nearly all this increase was accounted for by students from the People's Republic of China, who increased their share from near zero in 1982 to 22% of all the science and engineering PhDs earned by temporary-visa holders in 1992.

TABLE B-28 **Region and Country of Origin of Foreign Citizens with Temporary Visas Earning Science and Engineering PhDs, 1983 and 1993**

Country	1983	1993
TOTAL	3,400 (100.0%)	8,087 (100.0%)
East Asia	958 (28.2%)	4,335 (53.6%)
Taiwan	438 (12.9%)	1,055 (13.0%)
PRC	3 (0.1%)	1,745 (21.6%)
Korea	136 (4.0%)	1,027 (12.7%)
West Asia	935 (27.5%)	1,538 (19.0%)
India	308 (9.1%)	789 (9.8%)
Africa	385 (11.3%)	374 (4.6%)
Europe	314 (9.2%)	838 (10.4%)
Other	808 (23.8%)	1,002 (12.4%)

SOURCE: Calculated from Table 5 in NSF, 1994f.

The annual reports of the Survey of Earned Doctorates conducted by the National Research Council for NSF have documented a substantial increase since 1970 in the time it has taken to obtain a PhD, whether measured in years since the bachelor's degree or in years registered in graduate school. According to these reports, which calculate the median time-to-degree (TTD) of all those obtaining PhDs each year, the figure has increased by about 30% over the last 20 years.

According to the latest report of the Survey of Earned Doctorates, total TTD (years from bachelor's degree to doctorate), or TTTD, went up by 29.6% from 1967 to 1993, from 8.1 to 10.5 years (Table B-29). The trend in registered time-to-degree (RTTD) was similar—31.5% (from 5.4 to 7.1 years). However, 1967 was near the postwar total-TTD low of 8 years reached in 1970. TTTD increased for decades (from 7 years in 1920 to 9 in 1962), fell during the 1960s to the low of 8 years in 1970, and then resumed its upward trend after 1970 (Bowen and Rudenstine, 1992:Figure 6.3).

Those figures are for all PhDs in all fields, including humanities, education, and the professional (which have had the highest TTDs historically). The patterns vary widely by field, even within the sciences and engineering. Engineering and physical sciences have always had shorter than average completion times; social sciences, longer.

The increase in TTD has slowed considerably since about 1987, even though the recession of the early 1990s might have increased the incentive to stay in school a year or two longer.

TABLE B-29 **Median Total Time-to-Degree for Doctorate Recipients, 1962-1993 (selected years)**

Field	1962	1967	1972	1977	1982	1987	1992	1993
All fields (including humanities)								
Registered	5.4	5.4	5.7	6.1	6.5	6.9	7.1	7.1
Total	8.8	8.1	8.2	8.7	9.6	10.4	10.5	10.5
All Science and Engineering								
Registered						6.4	6.7	6.7
Total						8.6	9.1	9.2
Physical sciences								
Registered	5.1	5.1	5.6	5.7	5.8	6.0	6.5	6.5
Total	6.5	6.0	6.5	6.9	6.9	7.4	8.1	8.3
Life sciences								
Registered	5.3	5.4	5.5	5.7	6.0	6.5	6.7	6.8
Total	7.8	7.2	7.0	7.3	7.6	8.8	9.4	9.4
Social sciences								
Registered	5.4	5.2	5.6	5.9	6.7	7.2	7.5	7.4
Total	9.0	7.7	7.5	8.0	9.2	10.4	10.6	10.4
Engineering								
Registered	5.0	5.2	5.5	5.6	5.7	5.8	6.2	6.3
Total	7.1	7.2	7.5	7.5	8.0	8.1	8.7	8.8

SOURCE: Calculated from Table 6 in NRC, 1995.

In conducting the research for their recent book *In Pursuit of the PhD,* Bowen and Rudenstine (1992:113-119), noticed that TTD figures were lower for their sample of 10 schools. They consulted demographers who suggested a different method for determining TTD that should be more accurate. The method used by the Office of Scientific and Engineering

Personnel (OSEP) and others determines the median number of TTD years for all those receiving their doctorates in a particular year. The demographers pointed out that this permits a bias if the cohorts entering graduate school are increasing or decreasing in size over time. Each entering class of PhD candidates has some fast finishers and some slow finishers. In a period such as the late 1950s and 1960s, when the number entering PhD programs was growing every year, the proportion of fast finishers showing up for their degrees a few years later increased and made the decreases in TTD larger than they would have been if cohorts had been steady. Similarly, when cohort sizes decrease, as they did in 1974-1984, the proportion of fast finishers getting their degrees a few years later goes down, increasing the apparent TTD. More recently, enrollments have gone up again, and that accounts for at least part of the decrease in TTD medians in the past several years.

Bowen and Rudenstine corrected for that bias by calculating average TTD of entering cohort, rather than graduating cohort. They asked, how long on the average, did it take those entering a PhD program (or getting their bachelor's degrees in year X to get their doctorates? They found that use of the entering-cohort method gave an increase in TTD of about 10% over the preceding 15-20 years, not 30%. They admitted that any lengthening in the already-long TTD is a serious problem but said that its magnitude and newness had been exaggerated.

A study of TTD by staff of OSEP reviewed the literature on the causes of increasing TTD (Tuckman, et al., 1990). They found that earlier studies had looked at sociological, demographic, economic, and institutional factors, although few had looked at them all and undertaken a causal analysis. They developed a model of TTD with five vectors of variables: family background characteristics, individual abilities and interests, tuition and financial aid, institutional environment and policies, and economic and social forces. They tested the model in 11 fields using data from the Survey of Earned Doctorates and found a variety of factors that affected registered time-to-degree (RTTD) or total time-to-degree (TTTD), including the availability and form of student support, labor-market conditions, sociodemographic characteristics of the doctorate recipients, and characteristics of the undergraduate and graduate institutions. Yet no factor or set of factors consistently explained the general upward trend in TTD. That might be because TTD is poorly measured (the study was based on the graduating, rather than the entering, cohort), or because the data are inadequate. They are aggregate data, and some measure the variables of interest only indirectly; other variables, such as increasing complexity of subject matter or the incentive for faculty to keep students longer as cheap labor on research projects, are not measured at all.

As for negative consequences, the following have been mentioned (Tuckman, et al., 1990):

- The increasing time spent in graduate school increases the time it takes for the supply of PhDs to respond to shifts in market demand, and that has both social and individual costs (if demand goes up, there are not enough qualified people; if it falls, highly capable people cannot be employed in their field of training).

- Increasing TTD will discourage some highly qualified candidates from staying in science (perhaps some of the most qualified students, who can more easily find attractive alternatives).
- Delayed start of career reduces the total years of productivity for society and the return on investment for the individual.

Bowen and Rudenstine (1992) also studied the effects of financial support in some detail in their 10-school sample. They found that it mattered. Students who received financial aid had much higher completion rates and shorter TTD than students who relied on their own resources. In the sciences, the form of the aid had an effect on completion and TTD; research assistantships had the best effect, fellowships a close second, and teaching assistantships the worst effect. They also found that the NSF fellowship program had been very successful in reducing median TTD (4.9 years versus 5.6 years for those who were not NSF fellows in an eight-university group). Interpreting such findings is problematic, however. Did the NSF fellows finish earlier because of the fellowship form of support itself or because they were selected through a rigorous process that selected more-motivated students?

In conclusion, both RTTD and TTTD have been increasing for a long time, with the exception of the 1960s. Presumably, the increases are caused in part by the increasing complexity of knowledge and techniques to be mastered in doctorate programs and in part by less-desirable or less-excusable reasons (e.g., an increase in tuition costs and a decrease in federal aid, which force students to work more during graduate school, or a desire of faculty to keep students working on research projects). They are also caused in part by the increasing participation of women and minority-group members, who generally have longer TTDs.

According to Bowen and Rudenstine, having outside aid does improve completion and TTD rates. The form of the aid—fellowships, research assistantships, or teaching assistantships—might have little independent effect.

Source of Support

The Survey of Earned Doctorates (SED) administered yearly by OSEP for NSF asks new PhDs to list their primary source of support during graduate school. The data for 1993 are displayed in Table B-30. It should be noted, however, that the nonresponse rate to this question was 34%, for unknown reasons (it was 23% in 1991, and 30% in 1992). It also should be noted that federally funded research assistantships are listed with other research assistantships under "university" because students often do not know the source of support for their research assistantships. Federal loans are listed under "personal." "Other" includes national fellowships, employer funds, and support from foreign governments, state governments, and other nonspecified sources. The "life sciences" include "health science" PhDs as well as the biological and agricultural scientists listed in the other tables in this appendix.

A brief analysis of the table shows that a relatively large percentage of the PhD recipients in social sciences are self-supporting—nearly half, compared with 10-15% of those in the physical sciences and engineering and a fifth of those in the life sciences.

PhDs in the life sciences receive the most direct federal support, probably resulting from the large fellowship and traineeship programs of the National Institutes of Health.

Most PhDs in the physical sciences and engineering, and to a lesser extent the life sciences, receive their primary support from their universities. That includes federally funded research assistantships, as well as other research and teaching assistantships.

TABLE B-30 **Primary Sources of Support for Science and Engineering Doctorate Recipients, by Broad Field, 1993** (percentages)

Field	Personal	University	Federal	Other
TOTAL	23.8	61.4	7.5	7.3
Physical sciences	12.1	77.9	4.5	5.4
Life sciences	21.4	56.8	14.4	7.4
Social sciences	47.8	41.6	5.0	5.6
Engineering	14.7	69.3	4.9	11.1

SOURCE: Calculated from Table 11 in NRC, 1995.

POSTDOCTORATE EMPLOYMENT PLANS

According to the SED, among new science and engineering PhDs who had definite postgraduation plans, the percentage planning to work in academe (college or university) was 48% in the early 1960s (NRC, 1978:Table 30). That figure increased to 57.0% in 1970 before falling steadily to 44.1% in 1980 (NSF, 1993b:Table 15) and 40.4% in 1993 (NSF, 1994f:Table 7). Meanwhile, the proportion of new science and engineering PhDs going to business and industry grew from about 22% in the 1960s to 26.5% in 1970 and 36.2% in 1993.

Note that Table B-31 does not include those with definite plans for postdoctoral study in the United States, almost all at universities. These numbered 2,789 in 1970, 3,571 in 1980, 4,676 in 1990, and 5,739 in 1993 (NSF, 1993b:Table 15, 1994f:Table 7).

It also should be noted that the percentage of science and engineering PhDs who had definite plans at the time of the SED survey fell from 76.6% in 1970 to 72.0% in 1980, 64.0% in 1990, and 60.1% in 1993 (NSF, 1993b:Table 15, 1994f:Table 7).

TABLE B-31 **Science and Engineering PhD Recipients with Definite Postgraduation Commitments in the United States, by Field and Type of Employer, 1970-1991**

Field	1970		1975	1980	1985	1990	1991	
	No.	Percentage					No.	Percentage
TOTAL	9,216	100.0	8,187	7,285	6,614	7,175	7,403	100.0
College/university	5,263	57.1	4,287	3,228	2,851	2,952	3,099	41.9
Elementary/ secondary school	44	0.5	99	113	95	81	111	1.5
Government	1,015	11.0	1,365	1,142	885	871	890	12.0
Nonprofit organization	408	4.4	443	537	502	493	492	6.6
Industry/business	2,399	26.0	1,886	2,139	2,099	2,452	2,488	33.6
Self-employed	48	0.5	71	101	145	240	229	3.1
Other and unknown	39	0.4	36	25	37	86	94	1.3

SOURCE: Calculated from Table 5 in NSF, 1993b.

POSTDOCTORAL STUDY TRENDS

TABLE B-32 **Postdoctoral Study Plans of Recipients of Science and Engineering Doctorates from US Universities, 1985-1992**

PhD Recipients	1985	1987	1988	1989	1990	1991	1992
TOTAL	19,164	20,203	21,411	22,294	23,440	24,543	25,248
Postdoctoral plans	5,941	6,728	7,216	7,268	8,087	8,811	9,316
Fellowship	49.0%	48.0%	48.7%	49.7%	49.0%	49.9%	50.7%
Research associate	41.3%	42.9%	43.0%	40.5%	41.7%	41.5%	41.2%
Traineeship	4.5%	3.6%	3.9%	4.0%	4.1%	3.9%	3.3%
Other	5.2%	5.1%	4.4%	5.5%	4.9%	5.0%	5.1%

SOURCE: Calculated from Appendix Table A-3 in NRC, 1993.

TABLE B-33 **Postdoctoral Study Plans of Recipients of Science and Engineering Doctorates from US Universities, by Field, 1992**

PhD Recipients	Physical Sciences	Engi-neering	Life Sciences	Social Sciences	Total Science and Engineering
TOTAL	6,498	5,437	7,108	6,205	25,248
Postdoctoral plans	3,022	1,202	4,066	1,036	9,316
Fellowship	53.1%	34.4%	57.5%	64.7%	50.7%
Research associate	42.8%	58.8%	32.3%	19.2%	41.2%
Traineeship	2.2%	4.1%	2.6%	9.6%	3.3%
Other	1.9%	3.2%	7.7%	6.6%	5.1%

SOURCE: Calculated from Appendix Table A-3 in NRC, 1993.

TABLE B-34 **Science and Engineering Postdoctoral Appointees in Doctorate-Granting Institutions, by Field, 1982-1992**

Field	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
All Science and Engineering	14,672	15,657	16,168	16,920	17,901	18,760	19,759	20,962	21,604	23,018	24,024
Science, Total	13,694	14,556	14,974	15,573	16,505	17,319	18,075	19,054	19,661	20,781	21,680
Physical sciences	4,281	4,444	4,386	4,517	4,843	4,953	5,187	5,355	5,507	5,623	5,772
Physics	1,326	1,350	1,320	1,342	1,527	1,548	1,578	1,678	1,715	1,763	1,954
Chemistry	2,805	2,973	2,906	2,995	3,151	3,246	3,429	3,462	3,580	3,627	3,573
Environmental sciences	335	415	488	375	417	420	499	459	605	645	709
Mathematical sciences	194	170	203	226	201	228	280	223	247	206	201
Computer sciences	46	82	63	74	74	100	91	78	71	157	149
Agricultural sciences	279	307	375	373	409	441	454	512	529	574	634
Biological sciences	7,756	8,355	8,707	9,164	9,722	10,346	10,752	11,518	11,799	12,648	13,287
Psychology	520	435	422	495	517	454	493	535	457	503	521
Social sciences	283	348	330	349	322	377	319	374	446	425	407
Engineering, Total	978	1,101	1,194	1,347	1,396	1,441	1,684	1,908	1,943	2,237	2,344
Chemical engineering	174	198	245	273	295	309	423	466	551	578	554
Materials	166	204	168	245	250	283	325	323	370	401	458
Mechanical	130	182	196	207	239	216	216	302	218	329	355
Electrical	176	174	171	176	172	175	186	193	241	300	307

SOURCE: Calculated from Table C-25 in NSF, 1992a; and, for 1991 and 1992, NSF, unpublished tables.

TABLE B-35 **Trends in Net Growth of Science and Engineering Postdoctoral Appointee Positions in Doctorate-Granting Institutions, by Field, 1982 and 1992**

Field	Growth, 1982-1992				Percentage Distribution of Postdoctoral Positions Among All Fields	
	1982	1992	Difference	Percentage	1982	1992
All Science and Engineering	14,672	24,024	9,352	63.7	100.0	100.0
Science, Total	13,694	21,680	7,986	58.3	93.3	90.2
Physical sciences	4,281	5,772	1,491	34.8	29.2	24.0
Physics	1,326	1,954	628	47.4	9.0	8.1
Chemistry	2,805	3,573	768	27.4	19.1	14.9
Environmental sciences	335	709	374	111.6	2.3	3.0
Mathematical sciences	194	201	7	3.6	1.3	0.8
Computer sciences	46	149	103	223.9	0.3	0.6
Agricultural sciences	279	634	355	127.2	1.9	2.6
Biological sciences	7,756	13,287	5,531	71.3	52.9	55.3
Psychology	520	521	1	0.2	3.5	2.2
Social sciences	283	407	124	43.8	1.9	1.7
Engineering, Total	978	2,344	1,366	139.7	6.7	9.8
Chemical engineering	174	554	380	218.4	1.2	2.3
Materials	166	458	292	175.9	1.1	1.9
Mechanical	130	355	225	173.1	0.9	1.5
Electrical	176	307	124	74.4	1.2	1.3

SOURCE: Calculated from Table C-25 in NSF, 1992a; and, for 1991 and 1992, NSF, unpublished tables.

TABLE B-36 **Appointments of Postdoctoral Scientists and Engineers Who Were Not US Citizens in Doctorate-Granting Institutions, by Field, 1982 and 1992**

Field	Growth, 1982-1992				Percentage of All Postdocs within Field		Percentage of All Non-US Science and Engineering Postdocs	
	1982	1992	Difference	Percentage	1982	1992	1982	1992
All Science and Engineering	5,961	12,627	6,666	111.8	40.6	52.6	100.0	100.0
Science, Total	5,304	11,053	5,749	108.4	38.7	51.0	89.0	87.5
Physical sciences	2,367	3,506	1,139	48.1	55.3	60.7	39.7	27.8
Physics	673	1,099	426	63.3	50.8	56.2	11.3	8.7
Chemistry	1,661	2,311	650	39.1	59.2	64.7	27.9	18.3
Environmental sciences	121	276	155	128.1	36.1	38.9	2.0	2.2
Mathematical sciences	126	109	-17	-13.5	64.9	54.2	2.1	0.9
Computer sciences	12	50	38	316.7	26.1	33.6	0.2	0.4
Agricultural sciences	116	275	159	137.1	41.6	43.4	1.9	2.2
Biological sciences	2,397	6,574	4,177	174.3	30.9	49.5	40.2	52.1
Psychology	65	127	62	95.4	12.5	24.4	1.1	1.0
Social sciences	100	136	36	36.0	35.3	33.4	1.7	1.1
Engineering, Total	657	1,574	917	139.6	67.2	67.2	11.0	12.5
Chemical engineering	133	415	282	212.0	76.4	74.9	2.2	3.3
Materials	138	331	193	139.9	83.1	72.3	2.3	2.6
Mechanical	100	211	111	111.0	76.9	59.4	1.7	1.7
Electrical	94	186	92	97.9	53.4	60.6	1.6	1.5

NOTE: Includes permanent residents and those with temporary visas.

SOURCE: Calculated from Table C-30 in NSF, 1992a; and, for 1991 and 1992, NSF, unpublished tables.

TABLE B-37 **Federally Supported Science and Engineering Postdoctoral Appointees in Doctorate-Granting Institutions, by Field, 1982 and 1992**

Field	Growth, 1982-1992				Percentage of All Postdocs within Field		Percentage of All Federally Supported Postdocs	
	1982	1992	Difference	Percent	1982	1992	1982	1992
All Science and Engineering	11,119	17,660	6,541	58.8	75.8	73.5	100.0	100.0
Science, Total	10,447	16,050	5,603	53.6	74.8	74.0	94.0	90.9
Physical sciences	3,600	4,589	989	27.5	64.1	79.5	32.4	26.0
Physics	1,156	1,641	485	42.0	87.2	84.0	10.4	9.3
Chemistry	2,307	2,730	423	18.3	82.2	76.4	20.7	15.5
Environmental sciences	255	556	301	118.0	76.1	78.4	2.3	3.1
Mathematical sciences	46	143	97	210.9	23.7	71.1	0.4	0.8
Computer sciences	25	113	88	352.0	54.3	75.8	0.2	0.6
Agricultural sciences	166	417	251	151.2	59.5	65.8	1.5	2.4
Biological sciences	5,825	9,695	3,870	66.4	75.1	73.0	52.4	54.9
Psychology	392	358	-34	-8.7	75.4	68.7	3.5	2.0
Social sciences	138	179	41	29.7	48.8	44.0	1.2	1.0
Engineering, Total	672	1,610	938	139.6	68.7	68.7	6.0	9.1
Chemical engineering	100	340	240	240.0	57.5	61.4	0.9	1.9
Materials	121	284	163	134.7	72.9	62.0	1.1	1.6
Mechanical	94	250	156	166.0	72.3	70.4	0.8	1.4
Electrical	118	229	111	94.1	67.0	74.6	1.1	1.3

NOTE: These are postdoctoral appointees for whom federal agencies and programs are "the source of the largest amount of their support" (those supported by federal loans are not included).

SOURCE: Calculated from Table C-27 in NSF, 1992a; and, for 1991 and 1992, NSF, unpublished tables.

TABLE B-38 **Sources of Support for Science and Engineering Postdoctoral Appointees in Doctorate-Granting Institutions, by Field, 1992**

Field	Total	Federal Sources				Non-Federal Sources
		Total	Fellowships (%)	Traineeships(%)	Research Grants(%)	
All Science and Engineering	24,024	17,660	11.1	7.6	81.3	6,364
Science, Total	21,680	16,050	11.8	8.2	80.0	5,630
Physical sciences	5,772	4,589	7.5	0.8	91.7	1,183
Physics	1,954	1,641	4.4	0.2	95.4	313
Chemistry	3,573	2,730	8.5	1.2	90.3	843
Environmental sciences	709	556	7.9	1.1	91.0	153
Mathematical sciences	201	143	16.1	4.2	79.7	58
Computer sciences	149	113	1.8	0.9	97.3	36
Agricultural sciences	634	417	9.8	0.5	89.7	217
Biological sciences	13,287	9,695	13.9	11.9	74.2	3,592
Psychology	521	358	14.2	23.5	62.3	163
Social sciences	407	179	27.4	14.5	58.1	228
Engineering, Total	2,344	1,610	3.7	1.1	95.2	734
Chemical engineering	554	340	0.9	0.9	98.2	214
Materials	458	284	1.1	0.0	98.9	174
Mechanical	355	250	4.4	2.4	93.2	105
Electrical	307	229	3.5	0.0	96.5	78

SOURCE: Calculated from NSF unpublished data.

C

EMPLOYMENT TRENDS AMONG SCIENTISTS AND ENGINEERS WITH GRADUATE DEGREES

Michael McGeary
Study Director, Committee on Science, Engineering, and Public Policy

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OVERVIEW

This appendix has two parts: an original "cohort" analysis of data on the employment of recent science and engineering (S&E) PhDs since 1973 and a review of data on the employment of new science and engineering master's-degree recipients.

EMPLOYMENT TRENDS AMONG RECENT COHORTS OF SCIENCE AND ENGINEERING DOCTORATES

To understand better the career prospects of recipients of advanced degrees in science and engineering, a thorough knowledge of trends in the recent employment-related histories of new graduates is helpful. A rich database for such an analysis exists, and a preliminary study is reported in this appendix. The database is the Survey of Doctorate Recipients (see Box C-1 on page 148 for a description of the SDR database and its potential uses and limitations).

NSF publishes tables of data from the SDR on the entire population of U.S. scientists and engineers (the most recent was of the 1991 survey; see NSF, 1994d). The tables are examined below, but they do not provide information about recent science and engineering PhDs. For this study, OSEP was asked to produce two series of data tables: (1) tables on the employment activities of scientists and engineers who had received science and engineering PhDs in the 1-4 years before each survey, and (2) tables on the employment activities of those receiving science and engineering PhDs 5-8 years before each survey. This type of cohort analysis was apparently last done in response to the "new depression" in academic employment of the middle 1970s (see, e.g., NRC, 1983).

In this appendix, 4-year "classes" or cohorts are used to ensure minimal sample size when looking at specific fields, such as mathematics, chemistry, and biology. For example, the first set of tables gives information on those getting PhDs in 1969-1972 at the time of the 1973 survey, those getting PhDs in 1971-1974 at the time of the 1975 survey, and so on, through those who earned PhDs in 1987-1990 at the time of the 1991 survey.

The tables present data on workforce status (full-time, part-time, or unemployed), employment sector (academe, other education, business and industry, government, etc.), and tenure status of those employed in academe (4-year colleges, universities, and medical schools). There are tables and/or figures for the following:

All scientists and engineers (excluding psychologists)
- Physical scientists
  - Mathematicians
  - Computer scientists
  - Physicists/astronomers
  - Chemists
  - Earth/atmospheric/ocean scientists
- Life scientists
  - Agricultural scientists
  - Medical scientists
  - Biological scientists
- Engineers
- Social scientists
- Psychologists

Employment Status: Full-Time, Part-Time, and Not Employed

1-4 Years Out For those 1-4 years after receipt of PhD at the time of each survey since 1973, the SDR data (not reproduced here) show that unemployment rates and part-time employment rates have been low in all fields. Overall, the percentage of unemployed (defined as not working and looking for work) has varied between 1.2% and 1.6%. It was 1.5% in 1991 among those getting PhDs in 1987-1990. This trend, or lack of a trend, holds for each field. It does not rule out, however, substantial increases in unemployment since 1991.

The percentage not employed for all reasons (e.g., not looking, retired, or unemployed) has also been low and steady since 1973, about 3%.

The proportion of new PhDs employed part-time has increased by about 50%—from 2% in 1973 to 3.1% in 1991 (totaling about 1,100 of 58,000 in 1973 and 2,000 of 63,000 in 1991). This trend was shown in all science fields, except that part-time employment tripled among new social scientists, from 2% to 6%. Part-time employment did not increase among new engineering PhDs (it has been about 1% since 1973).

The category with the most significant change has been the proportion of recent doctorates employed in postdoctoral appointments. Just 8% of the 1969-1972 PhDs were postdoctorates in 1973, a percentage that increased steadily to 19% of the 1985-1988 PhDs in 1989 (the 1991 survey was delayed six months, so the postdoctorate percentage is lower—14%). Most postdoctorates were among new biology PhDs (2,000 in 1973 and 6,300 in 1989), and most of the rest were in physics/astronomy and chemistry (1,900 in 1973 and 2,800 in 1989).

5-8 Years Out For those 5-8 years out at the time of each survey, the pattern is similar except that few are in postdoctoral appointments. The percentage of unemployed is generally lower than for those 1-4 years out—between 0.7% and 1.3%—but it increased to 1.9% in 1991.

The percentage not employed for other reasons was up a little in 1991, but 97% were still employed. The proportion employed part-time doubled to 3.2% in 1991 but was still low.

Conclusion If there are major employment changes or problems, they have arisen mostly since 1991. The employment statistics are all relatively good, but some were slightly worse in 1991 than in 1987 or 1989. Even that is difficult to interpret, because the survey procedures were changed in 1991 and the response rate was much higher.[1]

Employment Sector: Academe, Industry, Government

Figure C-1 shows where all science and engineering PhDs were employed 1-4 years after receiving their doctorates, and Figure C-2 shows where they were 4 years later (5-8 years after receiving their doctorates.); Tables C-1 and C-2 give the numbers and percentages on which the figures are based. Figure C-1 confirms the steadily growing proportion going into postdoctoral positions during the 1970s and 1980s (8% in 1973 and 19% in 1989, as noted above)[2] as well as the growing proportion going into business and industry (22% in 1973 and 29% in 1991). A smaller proportion went directly into academic employment (49% in 1973 and 40% in 1991)(presumably, some were going into postdoctoral positions instead).

Figure C-2 shows where science and engineering are 5-8 years after receiving their doctorates. Not surprisingly, few are in postdoctoral appointments, although the percentage increased from 2% to 3% over the period (but it increased from 4.8% in 1973 to 9.2% in 1989 among biologists 5-8 years out). The proportion employed in academe fell. More than half the 1969-1972 PhDs were employed in academe 5-8 years later, compared with 45% of the 1983-1986 graduates in 1991. **This trend is the basis of a major conclusion of the report—that most new PhDs are employed outside academe.**

Another way of looking at the trend is to compare the same "class" 1-4 years and 5-8 years out (Figures C-3 to C-5). Over the period, there is an increasing falloff from the number of those on postdoctorates and employed in academe in the first 1-4 years to the number employed in academe plus postdoctorates after 5-8 years (this is true, although to different degrees, across fields).

The growth sector was business and industry. After 5-8 years, 26% of science and engineering PhDs were employed in business and industry as of 1973, a proportion that grew to about 45% in 1991 (Figures C-3 through C-5).

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[1] As the report was going to press, after this was written, NSF released the preliminary results of the 1993 SDR. The unemployment rates were up slightly but still low (see text Figure 2-5).

[2] It is important to remember that some members of each 4-year cohort have already completed a postdoctoral assignment by the time of the survey. These figures are most useful for seeing trends.

The employment patterns differ from field to field (see Figures C-6 through C-18 for those 1-4 years out and Figures C-19 through C-31 for those 5-8 years out). Some fields such as chemistry and engineering, have long had a high percentage of PhDs working in industry; others have had high percentages working in academe. Within the sciences, however, the trends have been similar—a smaller proportion going into academe and the federal government, and a greater proportion going into business and industry (there was also noticeable growth in nonprofit employment among social scientists). Engineering is one field in which the percentage working in academe after 5-8 years, although relatively low, has increased (from 29% in 1979 to 32% most recently), as has the percentage working in business and industry (from 50% to 58%). The federal government was the big loser, going from 13% (1,600 of the class of 1969-1972 in 1977) to 5% (about 500 of the class of 1983-1986 in 1991).

Tenure Status

Table C-2 has some interesting data on trends in tenure and tenure status within academe among those 5-8 years after receiving the PhD. The number of academics with tenure fell both absolutely and relatively over the period. In 1979, for example, 20% of all those who had received their PhDs 5-8 years before (1971-1974) had tenure, and another 14% had tenure-track positions. The percentage with tenure after 5-8 years fell steadily to 12% in 1989, while the percentage in tenure-track positions grew to 17%. In absolute terms, the number with tenure after 5-8 years fell from 12,000 in 1979 to 6,500 in 1989, while the number in tenure-track positions went from 8,000 to 9,000. (The 1991 survey increased the percentage with tenure to at least 14%; the extent to which the change in survey methods contributed to this change needs to be explored.)

In another way of looking at the data, the total number in the tenure system of those 5-8 years after receiving the PhD fell from 20,000 in the 1979 survey to about 16,000-17,000 in the 1989-1991 survey, and the proportion with tenure decreased relative to those still in tenure-track jobs.

Meanwhile, a fairly steady number and percentage of PhDs 5-8 years out had non-tenure system positions over the period (about 7,000, or 12% of all PhDs 5-8 years out).

The figures differ from field to field, although the general trends hold. Biology is interesting because the percentage with tenure, low in 1979 at 18% fell to 7% in 1989, while those in tenure-track positions or not in the tenure system stayed about the same. Presumably, that reflects the high and growing proportion of postdoctorates and the lengthening time before biology PhDs enter faculty positions and begin their quest for tenure. In fact, as noted above, more than 9% of biologists were still in postdoctoral positions 5-8 years after receiving their PhDs. That in turn might be part of the explanation for the low and falling percentage of principal investigators under 35 years of age applying for National Institutes of Health research project grants, as reported in the recent National Research Council study of funding of young investigators (NRC, 1994a).

Impact of Employment Choices of Recent PhDs

The new data presented here on science and engineering 1-4 and 5-8 years after receiving their doctorates give a sense of the career-related flow of new PhDs. The flows also have an impact on the overall stock of PhDs. More than 14,000 new doctorates were added each year to the total stock of PhDs working in the United States, and small shifts in employment patterns have a cumulative impact over time on the whole. Table C-3 presents data on the employment of **all** US PhDs at the time of each survey.

- With 14,000 a year being added to a stock that was relatively young in 1973, the total number of employed science and engineering PhDs increased from 220,000 in 1973 to 437,000 in 1991.
- Although the percentage in academe (four-year colleges, universities and medical schools) fell from 57% to 49%, the absolute number increased from 125,000 in 1973 to 195,000 in 1991 (an increase of 56%).
- The overall percentage of those in academe with tenure grew from 58% in 1975 to 62% in 1983 and fell to 55% in 1991.
- The percentage employed in business and industry increased from 24% to 36%, or from 53,000 to 157,000 (an increase of 196 percent).

Conclusions

1. More than 14,000 new PhDs in science and engineering have found employment each year since the early 1970s. Unemployment rates of those out for 1-4 years or 5-8 years have been low compared with other occupations and fairly stable, at least through 1991. That does not reflect events since 1991, and it does not mean that all found work in their fields or found jobs that they expected or wanted.

As a result of the steady output of doctoral science and engineering, the overall number of people with science and engineering PhDs from U.S. universities working in the United States has nearly doubled since 1973. Academe has absorbed a large number, 70,000, or about 3,900 a year. Business and industry have absorbed another 104,000, or 5,800 a year. The latter has been the growth sector for PhD employment, and is likely to remain so for future PhDs.

2. Year by year, the proportion of new PhDs going into academe for employment has fallen steadily, with business and industry increasing their share of PhD employment. It is important to note that academe, while losing share, is still an important employer of new PhDs, and any changes in the academic employment market would have a substantial, if slowly declining, impact on the career prospects of new PhDs.

3. The increasing proportion of new PhDs taking postdoctoral appointments has been an important feature of some fields, especially biology (accounting for more than half) and some of the physical sciences. The percentage of those 5-8 years out, in postdoctoral positions, especially in biology, is increasing, indicating perhaps a lengthening of such positions or an increase in the practice of taking multiple postdoctorates. Those trends might account in part for the decreasing percentage of PhDs with tenure 5-8 years out, because it postpones beginning of an independent faculty career. Also, increasing numbers of postdoctorates are going into nonacademic employment.

4. The data do not show a substantial increase in part-time employment or in nontenure positions in academe, at least through 1991. However, a large percentage (12%) and number (7,000) of recent PhDs, all those 5-8 years out, have been in such positions through the period. Who are they and what are they doing?

5. This analysis should be extended by looking at data on such matters as salary (academe versus business versus government), primary activity (e.g., basic or applied research, development, R&D management, teaching, or consulting), and field-switching.

The Survey of Doctorate Recipients (SDR) is a biennial survey that has gathered employment-related information from a nationally representative panel of PhDs from U.S. institutions since 1973 (it does not include anyone who received a doctorate from a foreign institution). It is conducted by the Office of Scientific and Engineering Personnel (OSEP) of the National Research Council (NRC) for the National Science Foundation (NSF), National Institutes of Health (NIH), and other federal agencies. For each survey, a sample of new doctorate recipients since the preceding survey is added that is representative of all U.S. citizens and foreign citizens who stay in the United States. Although NSF publishes tables of information based on the entire sample, it is possible to use the SDR database to compare the employment situations of PhD "classes" over time. For this report, for example, we had tables produced of the employment characteristics of doctoral scientists and engineers who had received their PhDs 1-4 and 5-8 years before each survey to see how the employment situations of "new" or "recent" PhDs have changed over time by field (much more such work could be done, involving more detail and additional variables-e.g., citizenship and sex-to understand better the careers of doctoral scientists and engineers).

During the 1980s, the response rate to the SDR fell steadily. NRC studies in 1975 and 1989 indicated that nonresponse bias resulted in overestimates of the number of employed scientists and engineers, especially in academe but also overall (Spisak and Maxfield, 1979; Mitchell and Pasquini, 1991). In 1989, for example, the difference in academic employment was estimated to be about 5 percentage points. A recent NSF analysis concluded that the overestimates had been consistent over time and therefore did not affect the trend line of steady growth since 1973 (NSF, 1992b).

In 1991, several changes were made in the SDR that affect the comparability of the 1991 results with earlier data. The overall response rate was improved substantially, from 58% in 1989 to 80%. That improved the quality of the 1991 estimates, but, as NSF noted, "the improved response rates and the expected lessening of bias should be considered additional sources of changes in time series and longitudinal analysis" (NSF, 1994d:66). The 1991 survey was also fielded 7 months later than earlier surveys, and that explains at least part of the drop in proportion of those in postdoctoral-study positions in the group 1-4 years after the PhD (from 18.7% in 1989 to 14.0% in 1991).

Because of the changes in survey response rates and timing, time-series comparisons involving 1991 should be interpreted with caution. In this report, for example, we do not use 1991 data at all to look at postdoctoral-study trends. We do use 1991 estimates of employment status because they are the most-accurate data on the current situation, and if the reader understands the procedural changes described here, they still provide a useful comparison with (and correction of) earlier data.

In 1993, most of the questions were also changed, which substantially limited comparability for all but a few basic characteristics (e.g., unemployment). The only data used from the 1993 survey, which appeared as this report was going to press, are unemployment rates.

Box C-1: Methodological note

TABLE C-1 Scientists and Engineers 1-4 Years After Receiving PhD from US Institutions, by Field, Employment Status, and Sector of Employment, 1973-1991

	Year of Survey.									
TOTAL	1973	1975	1977	1979	1981	1983	1985	1987	1989	1991
Total Population	58,121	59,618	57,343	55,075	53,518	54,119	55,324	56,227	58,825	63,010
(percentage)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Postdoctoral Study	4,652	6,315	7,280	7,307	7,725	7,956	8,919	9,390	10,978	8,803
(percentage)	8.0	10.6	12.7	13.3	14 4	14 7	16.1	16 7	18 7	14.0
Total Employed	50,934	51,595	47,848	45,887	44,218	44,250	44,815	45,029	46,098	51,935
(percentage)	87.6	86 5	83.4	83.3	82 6	81 8	81.0	80.1	78.4	82 4
4 Year/University/ Medical School	28,170	27,017	24,062	23,410	21,150	20,646	22,175	21,976	22,139	25,174
(percentage)	48.5	45.3	42.0	42.5	39 5	38.1	40.1	39.1	37.6	40.0
-tenured	3,468	4,206	3,168	2,483	1,764	1,829	1,347	1,122	1,029	1,482
(percentage)	6.0	7.1	5.5	4.5	3.3	3.4	2 4	2.0	1.7	2 4
-tenure track				11,771	12,648	11,761	13,262	12,363	12,057	14,313
(percentage)	0.0	0.0	0 0	21.4	23.6	21.7	24.0	22.0	20.5	22.7
-other/no reports	24,702	22,721	20,894	9,156	6,738	7,056	7,566	8,491	9,053	9,379
(percentage)	42.5	38.1	36.4	16.6	12.6	13.0	13.7	15.1	15.4	14.9
Other Educational Institutions	1,326	1,472	1,618	802	923	969	892	764	827	911
(percentage)	2.3	2 5	2 8	1.5	1.7	1 8	1.6	1 4	1.4	1 4
Business/Industry	12,550	14,086	13,962	13,615	15,009	16,120	15,634	15,177	15,435	18,280
(percentage)	21.6	23 6	24 3	24.7	28.0	29 8	28.3	27.0	26.2	29.0
US Government	5,400	5,347	4,379	4,104	3,681	3,154	2,641	2,992	3,527	3,465
(percentage)	9.3	9 0	7 6	7.5	6.9	5 8	4 8	5.3	6.0	5.5
State/Local Government	806	999	1,141	1,124	886	959	1,117	1,259	1,453	1,144
(percentage)	1.4	1.7	2.0	2.0	1.7	1.8	2.0	2.2	2.5	1.8
Nonprofit Organization	2,468	2,398	2,386	2,555	2,409	2,193	2,176	2,515	2,545	2,626
(percentage)	4.2	4 0	4 2	4 6	4.5	4 1	3.9	4.5	4.3	4.2
Other/No Report	214	276	300	277	160	209	180	346	172	335
(percentage)	0.4	0.5	0.5	0.5	0.3	0.4	0.3	0.6	0.3	0.5
Total Not Employed	2,535	1,708	2,215	1,881	1,534	1,913	1,590	1,808	1,749	2,272
(percentage)	4 4	2 9	3 9	3.4	2 9	3 5	2 9	3 2	3 0	3 6
-seeking	811	783	927	716	622	682	670	775	686	940
(percentage)	1.4	1.3	1.6	1.3	1.2	1.3	1.2	1 4	1 2	1.5
-not seeking	287	348	353	480	345	285	297	465	498	668
(percentage)	0.5	0.6	0.6	0.9	0.6	0.5	0.5	0 8	0.8	1.1
-retired	23	16	24	11	9	2	0	90	71	19
(percentage)	0.0	0.0	0 0	0.0	0.0	0.0	0.0	0.2	0.1	0.0
-other/no report	1,414	561	911	674	558	944	623	478	494	645
(percentage)	2.4	0.9	1.6	1.2	1.0	1.7	1.1	0.9	0.8	1.0

NOTES: This table compares cohorts of scientists and engineers 1-4 years after receiving a doctorate from a US university (e.g., 1969-1972 PhDs in 1973, 1971-1974 PhDs in 1975, and so on). All fields are included except psychology (for field-level data, see Figures C-6 through C-18). All percentages are of the total population, including those not in the workforce.

Due to changes in survey procedures and timing in the 1991 survey, the 1991 estimates are not entirely comparable to those for the earlier survey years (see methodological note in Box C-1 for further information on comparability of 1991 estimates).

SOURCE: Special runs of data on employment status and employment sector of US doctoral scientists and engineers from the Survey of Doctorate Recipients.

TABLE C-2 **Scientists and Engineers 5-8 Years after Receiving PhD from US Institutions, by Field, Employment Status, and Sector of Employment, 1977-1991**

	Year of Survey:							
TOTAL	1977	1979	1981	1983	1985	1987	1989	1991
Total Population	58,334	59,514	57,456	55,734	53,985	54,013	54,812	55,598
(percentage)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Postdoctoral Study	1,179	1,208	1,153	1,185	1,355	1,228	1,651	1,325
(percentage)	2.0	2.0	2.0	2.1	2.5	2.3	3.0	2.4
Total Employed	55,446	56,879	54,914	52,507	51,504	51,233	51,782	52,082
(percentage)	95.0	95.6	95.6	94.2	95.4	94.9	94.5	93.7
4 Year/University/ Medical School	29,561	27,673	26,467	25,165	24,831	24,063	24,468	23,879
(percentage)	50.7	46.5	46.1	45.2	46.0	44.6	44.6	42.9
-tenured	14,407	12,149	11,257	9,822	8,113	7,163	6,502	7,844
(percentage)	24.7	20.4	19.6	17.6	15.0	13.3	11.9	14.1
-tenure track		8,171	9,026	8,483	10,138	9,165	9,658	9,081
(percentage)	0.0	13.7	15.7	15.2	18.8	17.0	17.6	16.3
-other/no reports	15,154	7,353	6,184	6,860	6,580	7,735	8,308	6,954
(percentage)	26.0	12.4	10.8	12.3	12.2	14.3	15.2	12.5
Other Educational Institutions	1,357	1,174	1,032	805	977	847	721	883
(percentage)	2.3	2.0	1.8	1.4	1.8	1.6	1.3	1.6
Business/Industry	14,945	16,981	17,974	18,285	17,830	18,568	19,418	19,156
(percentage)	25.6	28.5	31.3	32.8	33.0	34.4	35.4	34.5
US Government	5,556	6,525	4,682	4,573	3,998	3,536	3,074	3,255
(percentage)	9.5	11.0	8.1	8.2	7.4	6.5	5.6	5.9
State/Local Government	932	1,034	1,158	1,129	1,044	1,080	1,090	1,773
(percentage)	1.6	1.7	2.0	2.0	1.9	2.0	2.0	3.2
Nonprofit Organization	2,693	3,070	3,175	2,401	2,683	2,865	2,741	2,774
(percentage)	4.6	5.2	5.5	4.3	5.0	5.3	5.0	5.0
Other/No Report	402	422	426	149	141	274	270	362
(percentage)	0.7	0.7	0.7	0.3	0.3	0.5	0.5	0.7
Total Not Employed	1,709	1,427	1,389	2,042	1,126	1,552	1,379	2,191
(percentage)	2.9	2.4	2.4	3.7	2.1	2.9	2.5	3.9
-seeking	761	515	452	735	373	563	498	1,058
(percentage)	1.3	0.9	0.8	1.3	0.7	1.0	0.9	1.9
-not seeking	286	453	473	529	312	483	498	571
(percentage)	0.5	0.8	0.8	0.9	0.6	0.9	0.9	1.0
-retired	56	66	57	82	63	59	78	100
(percentage)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
-other/no report	606	393	407	696	378	447	305	462
(percentage)	1.0	0.7	0.7	1.2	0.7	0.8	0.6	0.8

NOTES: This table compares cohorts of scientists and engineers 5-8 years after receiving a doctorate from a US university (e.g., 1969-1972 PhDs in 1977, 1971-1974 PhDs in 1979, and so on). All fields are included except psychology (for field-level data, see Figures C-19 through C-31). All percentages are of the total population, including those not in the workforce.

Due to changes in survey procedures and timing in the 1991 survey, the 1991 estimates are not entirely comparable to those for the earlier survey years (see methodological note in Box C-1 for further information on comparability of 1991 estimates).

SOURCE: Special runs of data from the Survey of Doctorate Recipients on employment status and employment sector of US doctoral scientists and engineers.

TABLE C-3A **Employed Doctoral Scientists and Engineers, by Field, 1973-1991**

Field	1973	1975	1977	1979	1981	1983	1985	1987	1989	1991
TOTAL	220,332	255,940	285,055	314,257	343,956	369,320	400,358	419,118	448,643	437,206
SCIENTISTS	184,551	213,507	240,005	263,915	286,917	307,775	334,505	351,350	373,860	367,440
Physical scientists	48,526	54,629	57,531	60,222	63,110	63,986	67,480	68,647	70,209	80,872
Chemists	30,769	35,825	37,412	39,659	41,910	41,298	43,735	44,136	45,649	48,967
Physicists/ Astronomers	17,757	18,804	20,119	20,563	21,200	22,688	23,745	24,511	24,560	31,905
Mathematical scientists	12,130	13,611	14,609	15,250	15,569	16,379	16,758	16,699	17,611	20,049
Mathematicians	10,661	11,864	12,846	12,843	13,024	13,589	13,957	13,878	14,867	16,546
Statisticians	1,469	1,747	1,763	2,407	2,545	2,790	2,801	2,821	2,744	3,503
Computer/ Information specialists	2,713	3,528	5,767	6,684	9,064	12,164	14,964	18,571	19,797	5,376
Environmental scientists	10,321	12,103	13,001	14,575	15,909	16,467	17,288	17,811	19,787	13,263
Earth scientists	8,552	9,500	9,715	11,083	11,990	12,523	13,202	13,577	15,138	9,745
Oceanographers	1,130	1,277	1,563	1,662	1,793	1,742	1,959	2,037	2,460	1,920
Atmospheric scientists	639	1,326	1,723	1,830	2,126	2,202	2,127	2,197	2,189	1,598
Life scientists	56,665	63,344	70,537	78,857	84,912	92,802	101,838	107,378	115,833	113,743
Biological scientists	36,798	39,036	42,069	45,617	49,621	55,205	59,871	61,985	67,250	88,188
Agricultural scientists	9,189	10,993	12,112	12,789	13,496	14,536	15,513	15,796	16,504	16,637
Medical scientists	10,678	13,315	16,356	20,451	21,795	23,061	26,454	29,597	32,079	19,047
Psychologists	24,782	30,001	33,652	37,848	42,829	46,645	52,182	56,378	60,596	65,672
Social scientists	29,414	36,291	44,908	50,479	55,524	59,332	63,995	65,866	70,027	68,465
Economists	9,674	11,814	12,970	13,978	15,990	16,958	17,925	17,837	18,588	19,241
Sociologists/ Anthropologists	65,311	7,910	9,471	10,198	11,007	12,056	12,692	12,933	13,529	18,094
Other social scientists	3,209	16,567	22,467	26,303	28,527	30,318	33,378	35,096	37,910	31,130
ENGINEERS	35,781	42,433	45,050	50,342	57,039	61,545	65,853	67,768	74,783	69,766
Aeronautical/ Astronomical	1,670	2,019	1,987	2,364	2,519	3,684	3,827	5,005	6,367	3,087
Chemical	4,458	5,368	5,603	6,166	7,146	6,992	7,122	6,923	7,959	10,633
Civil	3,100	3,772	4,066	5,157	6,089	5,317	6,396	6,479	6,951	7,512
Electrical/Electronic	7,057	8,538	8,284	8,597	10,630	12,696	14,248	12,601	15,088	16,994
Material science	4,462	4,784	5,244	5,732	6,085	7,422	7,259	8,088	8,280	6,230
Mechanical	3,257	4,033	4,648	5,245	5,370	5,657	6,594	6,711	7,390	8,680
Nuclear	1,264	1,680	1,773	2,286	2,061	2,329	2,377	2,151	2,437	1,903
Systems design	1,963	2,436	3,556	4,931	5,349	3,891	3,683	3,935	3,896	1,561
Other	8,550	9,803	9,889	9,864	11,790	13,557	14,347	15,875	16,415	13,166

NOTES: All numbers in the table are estimates derived from a sample.

All doctoral scientists and engineers employed in a science or engineering (S&E) field were categorized by their field of employment when that information was available. When it was not, or when the employment field was other than science or engineering, doctorate holders were categorized by their field of degree.

SOURCE: Calculated from NSF, 1991, and NSF, 1994d.

TABLE C-3B **Employed Doctoral Scientists and Engineers, by Employment-Related Characteristics, 1973-1991 (percentage distribution)**

Characteristics	1973	1975	1977	1979	1981	1983	1985	1987	1989	1991
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100 0	100.0	100.0	100 0
Type of employment										
Science/Engineering	93 6	93.9	91.9	91.7	91.4	88 6	91.3	90.3	90 4	89 7
Other/Unknown field	6 4	6.1	8.1	8.3	8 6	11.4	8.7	9.7	9 6	10 3
Sector of employment										
Business/Industry, Total	24 2	25 2	25.1	26 4	28 8	30.7	31.4	31.4	32 4	36.0
Not self-employed	22.2	22.9	22.5	23.1	24.6	25 8	25.6	24 8	25.1	27 1
Self-employed	2.0	2.3	2 6	3.3	4 3	4 9	5 8	6 6	7.2	8 8
Educational institution	58 7	58 2	57.5	55 5	54 4	53.1	52.9	52.2	51.5	47 2
University/4-year college	56 7	56 1	55.1	53 3	52.1	50 8	50.5	50.0	49 2	44 7
Other	2.0	2.1	2.3	2.2	2.3	2.3	2.4	2.2	2 2	2.5
Federal government (civilian)	8.3	7.4	7.5	7.6	7.3	7.0	6.6	6.6	6 5	6 3
State/Local government	1.9	1 9	1.9	1.9	1.9	2.1	2.1	2 2	2.3	2.4
Hospitals/Clinics	2.1	2.9	3.0	3.1	2.9	2 8	2 8	2 9	2.8	3 2
Other non-profits	3 6	3.3	3 6	4 0	3.7	3 2	3 4	3 7	3 6	3 6
Other/No response	1.2	1.0	1.5	1.5	1 1	1 1	.9	1 0	9	1.4
Primary work activity										
Research and development	32.4	32.2	32.8	31.7	34 9	33 8	33 1	36 8	37 1	36 0
Basic research	15.5	14.9	15 3	15 2	16 0	15.5	15 3	15 1	15.1	14 0
Applied research	13.0	12.9	12 8	11.7	13.5	12.8	12.3	17.2	17.4	16.4
Development	3.9	4 4	4 7	4 8	5.3	5.5	5.5	4 5	4 7	5.6
Management/Administration	20.9	20.2	21.3	23.0	17.6	16 7	17 4	16.2	16.4	15.6
of Research and Development	11.9	11.2	10.8	13.7	9.5	8 5	8.7	8 1	7 9	7.6
of Other	9 0	9.0	10.5	9.3	8 1	8 2	8 7	8.1	8.5	8.0
Teaching	36.3	35.6	31.9	29 4	30 6	29.3	27.9	26.2	25.1	22.7
Professional services	3.3	4 0	4 7	5.8	6.7	7 1	7 9	7 8	8 2	9 1
Reports/Statistics/										
Computer activity	1/	1/	1/	1/	1/	1/	1/	2 8	2.9	3.6
Consulting	1.8	2.2	2.2	2.9	3.5	3.5	3.5	3.3	3.7	4 4
Other/No response	5 2	5.8	7.2	7 2	6.7	10.2	10.2	6 9	6 6	8 5
Federal support										
Receiving support	45.2	43.0	42.0	40 3	36.9	32.3	32.3	43.7	44 2	40.7
Not receiving support	50.3	53.5	53.7	54 4	46.8	52.3	52.3	52.7	53.0	55.7
Status unknown/No response	4.5	3.5	4 2	5.3	16.3	15 4	15 4	3 6	2.7	3 5

1/ This category was first introduced in 1987 to conform to other data series produced by NSF.

NOTE. All numbers in the table are estimates derived from a sample.

SOURCE: Calculated from NSF, 1991, and NSF, 1994d.

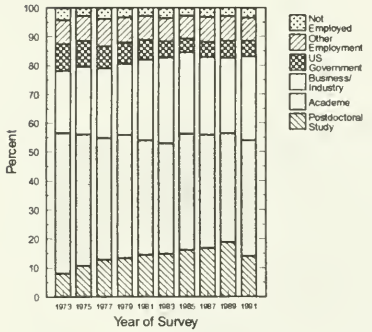

FIGURE C-1 Employment of all scientists and engineers 1-4 years after US PhD.

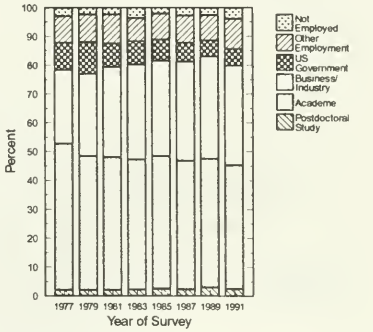

FIGURE C-2 Employment of all scientists and engineers 5-8 years after US PhD.

SOURCE: Tables C-1 and C-2

NOTES: See notes to Table C-1 and methodological note in Box C-1 for important information on the comparability of 1991 estimates with earlier estimates.

Not employed includes those seeking work (i.e., unemployed), not seeking work, retired, otherwise not working, or not reporting employment status.

Other employment includes other education (junior colleges, 2-year colleges, technical institutes, and elementary, middle, and secondary schools); state and local governments; hospitals and clinics; private foundations and other nonprofit organizations; other employers; and those who did not respond to the employment-sector question.

Business/industry includes self-employed.

Academe includes those employed at 4-year colleges, universities, and medical schools (including university-affiliated hospitals and medical centers).

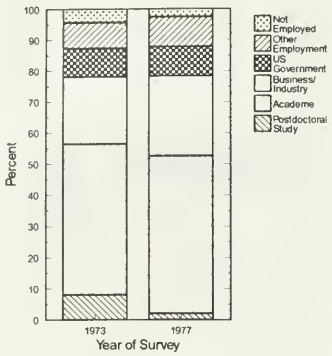

FIGURE C-3 1969-1972 science and engineering PhD recipients 1-4 and 5-8 years later.

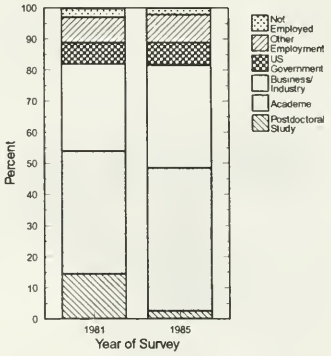

FIGURE C-4 1977-1980 science and engineering PhD recipients 1-4 and 5-8 years later

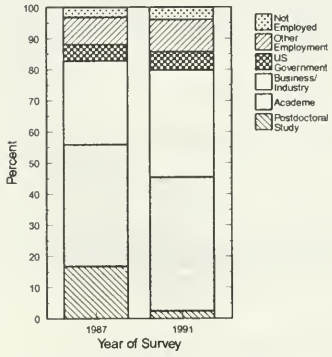

FIGURE C-5 1983-1986 science and engineering PhD recipients 1-4 and 5-8 years later.

SOURCE: Tables C-1 and C-2.

NOTES: See notes to Table C-1.

NOTES: Figures C-6 through C-18 compare cohorts of scientists and engineers 1-4 years after receiving a doctorate from a US university (e.g., 1969-1972 PhDs in 1973, 1971-1974 PhDs in 1975, and so on). Figures C-19 through C-31 compare cohorts of scientists and engineers 5-8 years after receiving a doctorate from a US university (e.g., 1969-1972 PhDs in 1977, 1971-1974 PhDs in 1979, and so on). All percentages are of the total population, including those not in the workforce.

Due to changes in survey procedures and timing in the 1991 survey, the 1991 estimates are not entirely comparable to those for the earlier survey years (see methodological note in Box C-1 for further information on comparability of 1991 estimates).

SOURCE: Special runs of data from the Survey of Doctorate Recipients on employment status and employment sector of U.S. doctoral scientists and engineers.

FIGURES C-6 THROUGH C-31

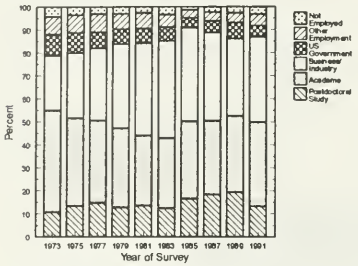

FIGURE C-6 Employment of physical scientists 1-4 years after US PhD

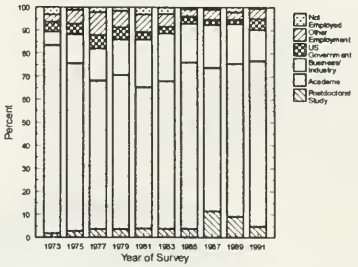

FIGURE C-7 Employment of mathematicians 1-4 years after US PhD

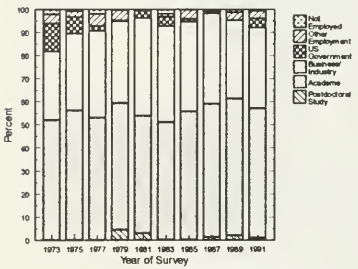

FIGURE C-8 Employment of computer scientists 1-4 years after US PhD.

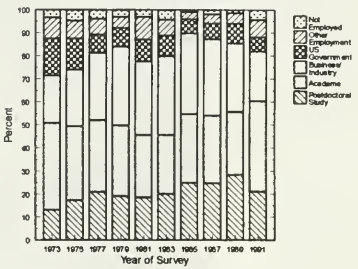

FIGURE C-9 Employment of physicists/astronomers 1-4 years after US PhD

FIGURE C-10 Employment of chemists 1-4 years after US PhD.

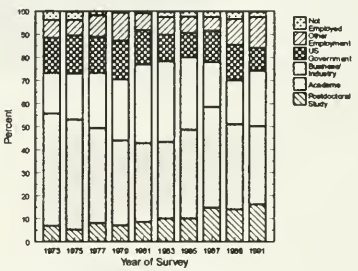

FIGURE C-11 Employment of environmental scientists 1-4 years after US PhD.

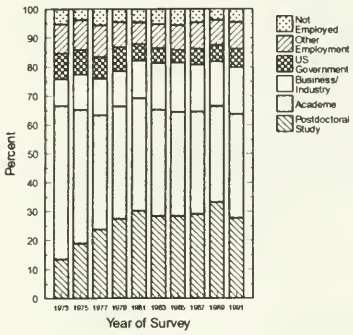

FIGURE C-12 Employment of life scientists 1-4 years after US PhD

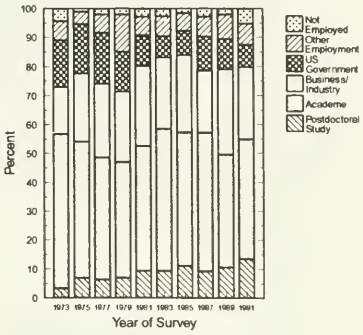

FIGURE C-13 Employment of agricultural scientists 1-4 years after US PhD.

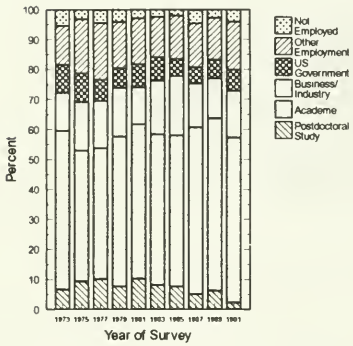

FIGURE C-14 Employment of medical scientists 1-4 years after US PhD.

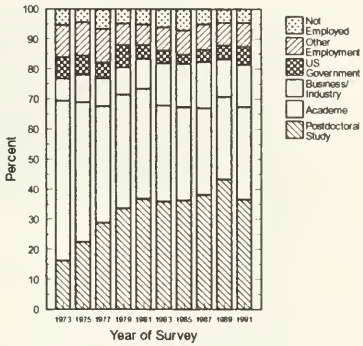

FIGURE C-15 Employment of biological scientists 1-4 years after US PhD.

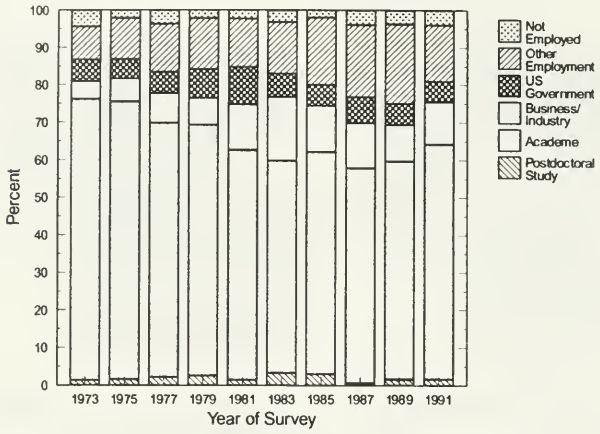

FIGURE C-16 Employment of social scientists 1-4 years after US PhD

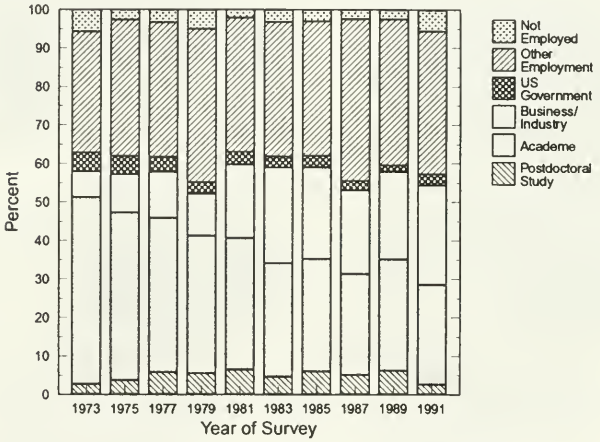

FIGURE C-17 Employment of psychologists 1-4 years after US PhD.

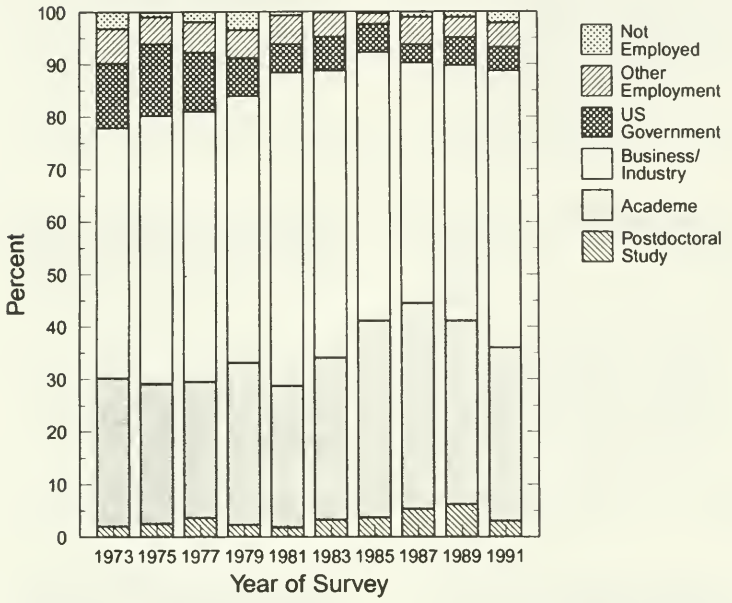

FIGURE C-18 Employment of engineers 1-4 years after US PhD.

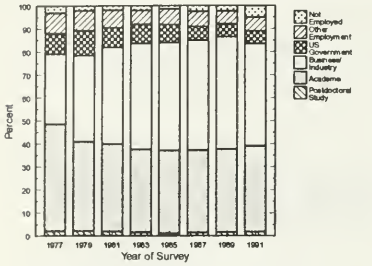

FIGURE C-19 Employment of physical scientists 5-8 years after US PhD.

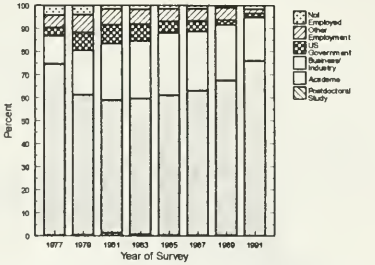

FIGURE C-20 Employment of mathematicians 5-8 years after US PhD.

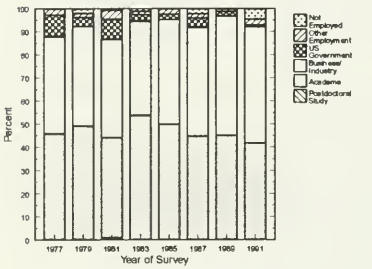

FIGURE C-21 Employment of computer scientists 5-8 years after US PhD.

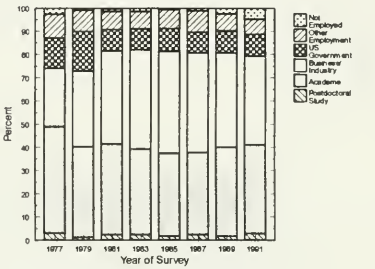

FIGURE C-22 Employment of physicists/astronomers 5-8 years after US PhD.

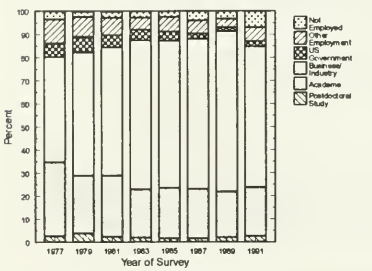

FIGURE C-23 Employment of chemists 5-8 years after US PhD.

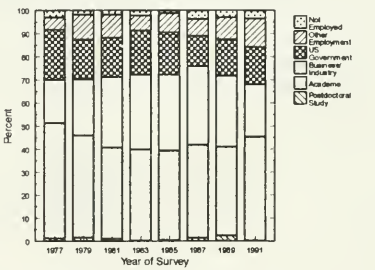

FIGURE C-24 Employment of environmental scientists 5-8 years after US PhD.

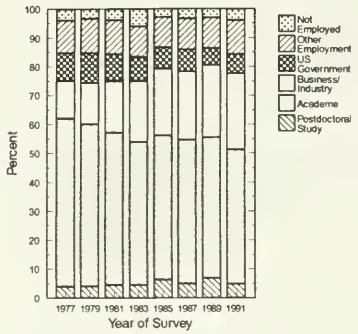

FIGURE C-25 Employment of life scientists 5-8 years after US PhD

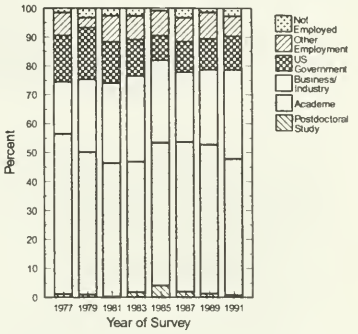

FIGURE C-26 Employment of agricultural scientists 5-8 years after US PhD

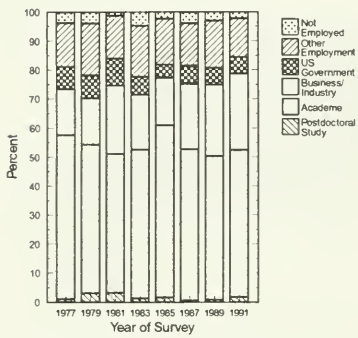

FIGURE C-27 Employment of medical scientists 5-8 years after US PhD

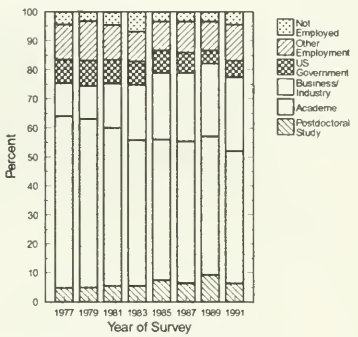

FIGURE C-28 Employment of biological scientists 5-8 years after US PhD

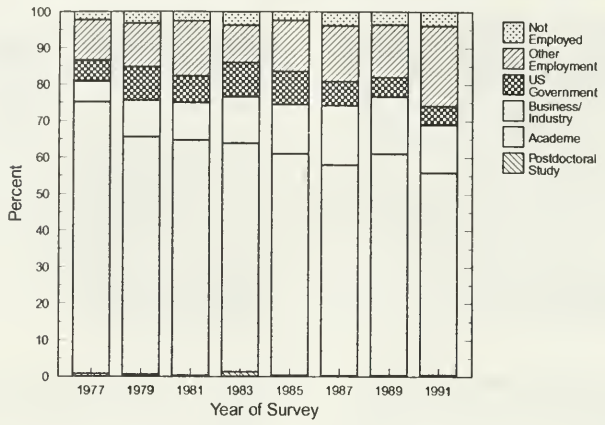

FIGURE C-29 Employment of social scientists 5-8 years after US PhD

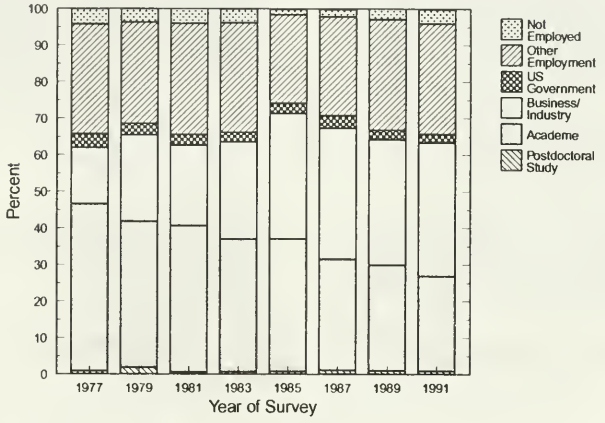

FIGURE C-30 Employment of psychologists 5-8 years after US PhD

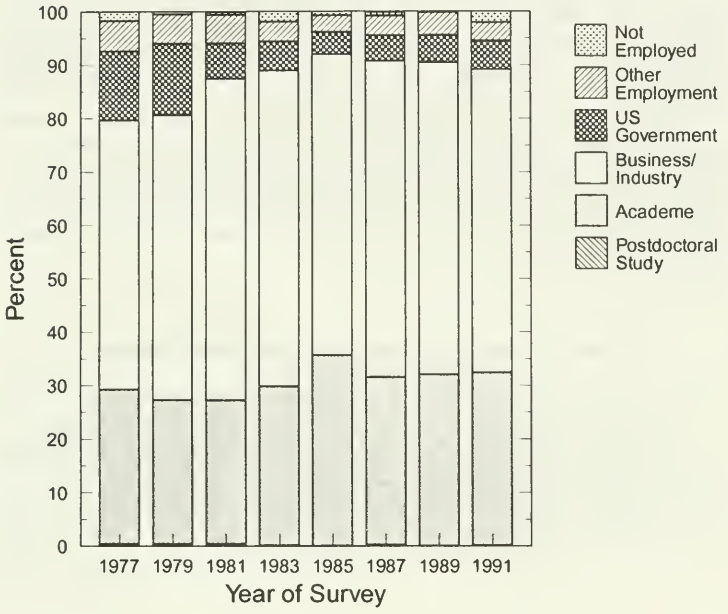

FIGURE C-31 Employment of engineers 5-8 years after US PhD.

EMPLOYMENT OF RECENT SCIENCE AND ENGINEERING MASTER'S DEGREE RECIPIENTS

The National Science Foundation conducts biennial surveys of recent recipients of master's and bachelor's degrees in various science or engineering fields. The latest published data are from the survey administered in the spring of 1990 to a sample who received science and engineering degrees during the 1987-1988 (1988) and 1988-1989 (1989) academic years (NSF, 1992a). Surveys conducted in 1982 (NSF, 1984), 1984 (NSF, 1986), 1986 (NSF, 1987), and 1988 (NSF, 1990a) are also reported here. A more recent survey was fielded in 1993 and is scheduled to be published shortly.

The NSF survey of recent college graduates and master's-degree recipients collects information on demographic and education characteristics and on early career-development experiences, such as employment status, reasons for unemployment, and attributes of employment including occupational classification, major activity, and salary. The survey is based on a nationally representative sample and is used to derive national estimates of the numbers and demographic, education, and employment characteristics of recent graduates in science and engineering.

How Many Science and Engineering Master's Degree Recipients Continue Graduate Study?

The number of new science and engineering master's-degree recipients in 1989 continuing as full-time students in 1990 was 16,200, or about 23% of the estimated 70,400 who received master's degrees in 1989 (another 4,900, or 7%, were part-time students)(Table C-4). The comparable percentage and number of continuing students among new master's-degree recipients in the 1980s surveys were about 21% and 10,000 - 13,000.

TABLE C-4 **Graduate-School Status One Year Later of Recipients of New Master's Degrees in Science and Engineering, 1982-1990**

	Master's Received in				
Status	1981	1983	1985	1987	1989
New science and engineering master's	46,700	47,500	61,100	58,100	70,400
Full-time students					
Number	9,800	10,300	13,000	12,200	16,200
Percentage	21.0%	21.7%	21.3%	21.0%	23.0%
Part-time students					
Number	4,300	4,200	4,700	3,300	4,900
Percentage	9.2%	8.8%	7.7%	5.7%	7.0%

SOURCE: Calculated from Table B-28 in NSF, 1984; Table B-28 in NSF, 1986; Table B-31 in NSF, 1987; Table B-31 in NSF, 1990a; and Table B-31 in NSF, 1992b.

Continued Education of New Science and Engineering Master's-Degree Recipients

The tendency to continue graduate studies full-time varies across fields but has increased in most fields since 1982. Barely 7% of those receiving master's degrees in computer science in 1989 were full-time students the next year, compared with 60% of those with new physics/astronomy master's degrees (Table C-5). The proportion of new master's-degree recipients going to graduate school part-time also varies from field to field but has gone down since 1982. The ratio of full-time to part-time graduate students a year after receipt of master's degrees also varies by field. In fields where the master's degree is usually considered the working degree, the ratio is more nearly equal (e.g., 2.2:1 in engineering and 1:1 in computer science and technology) than in fields where the PhD is considered the minimal professional credential (e.g., 3.6:1 in physics/astronomy, 22.6:1 in biology, and apparently higher in chemistry).

TABLE C-5 **Science and Engineering Master's-Degree Recipients Continuing in Graduate School the Next Year, 1982 and 1990 (percentages)**

	Master's Received in 1981		Master's Received in 1989	
	Full-Time Student	Part-Time Student	Full-Time Student	Part-Time Student
All science and engineering master's	21.0	9.2	23.0	7.0
Physical sciences	33.3	11.1	43.5	6.5
Physics/Astronomy	50.0	[a]	60.0	16.7
Chemistry	33.3	13.3	43.8	[a]
Other Physical sciences	25.0	25.0	11.1	[a]
Mathematics/Statistics	17.1	9.8	21.6	7.8
Computer sciences	8.0	10.0	7.1	7.1
Environmental sciences	17.6	5.9	20.0	8.0
Life sciences	27.9	9.3	32.0	4.1
Agricultural sciences	25.0	9.4	27.8	8.3
Biological sciences	29.1	9.1	36.1	1.6
Social sciences	23.9	8.5	27.5	7.3
Psychology	33.3	16.7	41.9	7.0
Engineering	15.2	7.2	17.3	7.7

[a] Too few cases to report.

SOURCES: Calculated from Table B-28 in NSF, 1984, for 1981 data; and Table B-31 in NSF, 1992b, for 1989 data.

How Many Recent Science and Engineering Master's-Degree Recipients Are Unemployed?

Unemployment rates among recent science and engineering master's-degree recipients in the labor force are low. In 1990, among those awarded master's degrees in 1988 and 1998, unemployment was 1.8% overall, ranging from a low of 1.1% of mathematicians and statisticians to a high of 3.6% of psychologists (Table C-6). In most fields, the unemployment rate among recent master's-degree recipients was lower in 1990 than in 1982 and 1984 (in the aftermath of the 1980-1982 recession), but slightly higher than in 1988.

TABLE C-6 **Unemployment One Year Later Among Recipients of Master's Degrees in Science and Engineering, 1982-1990 (percentages)**[a]

	Master's Received in				
Field of Degree	1980-1981	1982-1983	1984-1985	1986-1987	1988-1989
All science and engineering master's	3.7	3.5	2.1	1.7	1.8
Physical sciences	3.0	3.6	1.4	2.9	2.1
Physics/Astronomy	[b]	[b]	[b]	[b]	2.2
Chemistry	2.0	6.3	1.3	3.1	1.9
Other Physical sciences	[b]	[b]	[b]	[b]	[b]
Mathematics/Statistics	4.1	2.7	1.5	1.1	1.1
Computer sciences	0.6	1.1	0.4	1.1	1.5
Environmental sciences	6.9	4.3	6.1	1.9	2.7
Life sciences	2.5	4.3	4.2	1.3	2.1
Agricultural sciences	1.6	4.3	4.6	0.3	2.5
Biological sciences	3.0	4.3	4.0	1.9	1.9
Social sciences	6.8	5.6	3.4	3.2	2.1
Psychology	9.3	2.7	4.4	2.5	3.6
Engineering	2.1	3.0	1.2	1.7	1.7

[a] Full-time graduate students are excluded.

[b] No rate computed for groups in which labor force is smaller than 1,500.

SOURCES: Calculated from Table B-45 in NSF, 1984; Table B-45 in NSF 1986; Table B-49 in NSF, 1987; Table B-47 in NSF, 1990a; and Table B-47 in NSF, 1992b.

How Many New Science and Engineering Master's-Degree Recipients Are Employed in Their Fields or Other Science and Engineering Occupations?

Although unemployment rates are comparatively low for those with master's degrees, not all are working in the fields of their degrees or in other science and engineering occupations. Overall, in 1990, fewer than two-thirds of science and engineering master's-degree recipients were working in the same fields as their degrees, and fewer than one-fifth were working in other science and engineering occupations (Table C-7). Exactly 17% were not employed in science and engineering occupations. This split varied by field, however, with 7.5% of engineers and 8% of computer scientists working outside science and engineering, compared with 37% of social scientists and 46% of psychologists. Only one-fourth of physicists and astronomers were working in their fields (25% were working in computer science and "other physical sciences," and 25% in engineering occupations) (NSF, 1992b:Table B-39).

TABLE C-7 **Employed New Science and Engineering Master's-Degree Recipients Working in Fields of Degrees or in Science and Engineering Occupations, 1990 (percentage)**[a]

Field of Degree	Same Field as Master's	Another Science and Engineering Occupation	Non-Science and Engineering Occupation
All 1989 science and engineering master's	64.7	18.1	17.0
Physical sciences	41.7	41.7	16.7
Physics/Astronomy	25.0	50.0	25.0
Chemistry	55.6	33.3	11.1
Other Physical sciences	25.0	50.0	25.0
Mathematics/Statistics	57.9	26.3	15.8
Computer sciences	78.2	13.9	7.9
Environmental sciences	65.0	25.0	10.0
Life Sciences	52.5	19.7	27.9
Agricultural sciences	52.2	26.1	21.7
Biological sciences	52.6	15.8	31.6
Social sciences	44.0	20.0	36.0
Psychology	41.7	12.5	45.8
Engineering	78.2	14.4	7.5

[a] Exclusive of full-time graduate students.
NOTE: Percentages may not add to 100 because of rounding.
SOURCE: Calculated from Table B-39 in NSF, 1992b.

Who Employs New Science and Engineering Master's-Degree Recipients?

In the last decade, nearly 60% of employed new science and engineering master's-degree recipients were working in the private sector (Table C-8). Less than 20% were employed by educational institutions, split about evenly between four-year colleges and universities and other institutions (two-year colleges and elementary and secondary schools).

TABLE C-8 **Type of Employer One Year Later of Recipients of Master's Degrees in Science and Engineering, 1982-1990**[a]

Employer	Master's Received in 1981	1983	1985	1987	1989
All employed science and engineering master's	34,100 100.0%	34,400 100.0%	45,600 100.0%	43,700 100.0%	51,700 100.0%
Educational institutions	6,000 17.6%	4,900 14.2%	6,800 14.9%	7,400 16.9%	9,300 18.0%
4-year college/ university				4,000 9.2%	4,600 8.9%
Other educational institution				3,400 7.8%	4,600 8.9%
Business and industry	20,000 58.7%	20,000 58.1%	25,400 55.7%	25,200 57.7%	30,700 59.4%
Nonprofit organization	900 2.6%	1,700 4.9%	1,600 3.5%	1,400 3.2%	1,000 1.9%
Federal government	2,200 6.5%	2,500 7.3%	3,900 8.6%	2,300 5.3%	3,600 7.0%
State/local government	2,500 7.3%	2,800 8.1%	4,100 9.0%	2,900 6.6%	2,900 5.6%
Other	2,300 6.7%	2,400 7.0%	3,600 7.9%	4,400 10.1%	4,200 8.1%
No report	100 0.3%	100 0.3%	200 0.4%	100 0.2%	[b]

[a] Full-time graduate students are excluded.

[b] Too few cases to report.

SOURCES: Calculated from Table B-32 in NSF, 1984; Table B-32 in NSF, 1986; Table B-36 in NSF, 1987; Table B-36 in NSF, 1990a; and Table B-36 in NSF 1992b.

Field-to-Field Differences in Employment Sector

The tendency to work in industry or for other types of employers varies by field. In 1990, for example, more than three-quarters of computer scientists worked in the private sector, compared with less than a third of life scientists (Table C-9).

TABLE C-9 **Type of Employer of New Recipients of Master's Degrees, by Field of Science and Engineering, 1990**[a]

Employer	Physical Sciences	Mathematics/ Statistics	Computer Sciences	Environmental Sciences	Life Sciences	Social Sciences	Psychology	Engineering
ALL	2,400	3,800	10,100	2,000	6,100	7,500	2,400	17,300
Educational institutions	800	1,600	800	200	2,300	2,400	700	600
	33.3%	42.1%	7.9%	10.0%	37.7%	32.0%	29.2%	3.5%
Four-Year college/ university	300	400	500	200	1,200	1,200	300	500
	12.5%	10.5%	5.0%	10.0%	19.7%	16.0%	12.5%	2.9%
Other educational institution	400	1,100	300	100	1,100	1,200	400	100
	16.7%	28.9%	3.0%	5.0%	18.0%	16.0%	16.7%	0.6%
Business and industry	1,200	1,700	7,800	1,200	1,900	2,700	900	13,200
	50.0%	44.7%	77.2%	60.0%	31.1%	36.0%	37.5%	76.3%
Nonprofit organization	100	100	100	[b]	100	300	100	100
	4.2%	2.6	1.0%		1.6%	4.0%	4.2%	0.6%
Federal government	100	200	400	200	600	700	100	1,400
	4.2%	5.3%	4.0%	10.0%	9.8%	9.3%	4.2%	8.1%
State/local government	100	[b]	200	200	700	1,000	100	600
	4.2%		2.0%	10.0%	11.5%	13.3%	4.2%	3.5%
Other	100	300	800	200	600	400	400	1,400
	4.2%	7.9%	8.0%	10.0%	9.8%	5.3%	16.7%	8.1%
No report	[b]	[b]	[b]	[b]	[b]	[b]	[b]	[b]

[a] Full-time graduate students are excluded.

[b] Too few cases to report.

SOURCE: Calculated from Table B-36 in NSF, 1992b.

D

Respondents to Call for Comments

The committee solicited comments on the current graduate education system from academia, industry, and students. These comments helped the committee formulate its views. The respondents to the call for comments are listed below.

Mary E. Adamson
Miles Inc.
Mobay Road
Pittsburgh, PA

John Ahearne
Executive Director
Sigma Xi
Research Triangle Park, NC

Jame S. Allen
Glaxo Research Institute
Research Triangle Park, NC

Lawrence F. Ayers
Executive Vice President
Utilities and Mapping Sciences
Intergraph Corp.
Huntsville, AL

John C. Bailar
Department of Epidemiology and Biostatistics
Montreal, Quebec, Canada

J.F. Bagley
University Programs Focus Group
Battelle
Pacific Northwest Laboratories
Richland, WA

Mary B. Bennett
Director of Operations
Glaxo Research Institute
Research Triangle Park, NC

William O. Berndt
Office of the Vice Chancellor for Academic Affairs
University of Nebraska
Omaha, NE

U. Narayan Bhat
Office of the Dean
Research and Graduate Studies
Southern Methodist University
Dallas, TX

Rockey K. Bandlish
Raleigh, NC

Peter Bingham
President
Philips Laboratories
Briarcliff Manor, NY

Marc H. Brodsky
Executive Director and
Chief Executive Officer
American Institute of Physics
College, Park, MD

Mary-Dell Chilton
Agricultural Biotechnology
CIBA-Geigy Corp.
Research Triangle Park, NC

Walter Cohen
Office of the Dean
Sage Graduate Center
Cornell University
Ithaca, NY

Henry H. Dearman
Dean, Graduate School
University of North Carolina
Chapel Hill, NC

Philip H. Francis
Vice President, Technology
Schneider North America
Palatine, IL

Chad Gaffield
Acting Dean
University of Ottawa
School of Graduate Studies & Research
Ottawa, Ontario, Canada

David L. Goodstein
Vice Provost
Professor of Physics and Applied Physics
California Institute of Technology
Pasadena, CA

Eileen G. Gorman
Glasgow Business Community 707
Newark, DE

William Green
Graduate Coordinator, Mathematics
School of Mathematics
Georgia Institute of Technology
Atlanta, GA

N.A. Gjostein
Director, Materials Research Laboratory
Ford Motor Company
Dearborn, MI

Lowell M. Greenbaum
Vice President for Research
Dean, Schooi of Graduate Studies
Medical College of Georgia
Augusta, GA

R.Z. Gussin
Corporate Vice President
Science and Technology
Johnson & Johnson
News Brunswick, NJ

Dennis Guthrie
Manager, University Relations
DOW
Midland, MI

Robert P. Guertin
Dean
Graduate School of Arts and Sciences
Tufts University
Medford, MA

Lawrence H. Hare
Director, Operations
Martin Marietta Specialty Components, Inc.
Largo, FL

Thomas P. Hogan
Dean
Graduate School
University of Scranton
Scranton, PA

Rae Ann Hallstrom
Babcock & Wilcox
Barberton, OH

Thomas M. Hellman
Vice President
Environmental Affairs
Bristol-Myers Squibb Co.
New York, NY

Roy C. Herrenkohl
Vice Provost for Research and Dean of Graduate Studies
Whitaker Laboratory
Bethlehem, PA

Joseph W. Helmick
Dean of Graduate Studies and Research
Texas Christian University
Fort Worth, TX

C. Dennis Ignasis
Office of the Vice President
University of Maryland Eastern Shore

Robert Carl Johnson
The Graduate School
Office of the Associate Provost and Dean
Miami University
Oxford, OH

Marie-Louise Kagan
Syracuse, NY

Fritz R. Kalhammer
Vice President
Strategic Research and Development
EPRI
Palo Alto, CA

Ronald S. Kane
Assistant Vice President for Academic Affairs
Graduate Studies
New Jersey Institute of Technology
Newark, NJ

Cliff Kottman
Intergraph Corp.
Reston, VA

Frederick J. Krambeck
Senior Consultant
Mobil Research and Development Corporation
Paulsboro Research Laboratory
Paulsboro, NJ

Michael A. Kriss
Director
Community Outreach Program
Center for Electronic Imaging Systems
University of Rochester
Rochester, NY

Henry S. Leonard
Professor and Director of
Graduate Studies
Northern Illinois University
DeKalb, IL

Diandra L. Leslie-Pelecky
Center for Materials Research & Analysis
University of Nebraska
Lincoln, NE

Charles N. Li
Dean
Graduate Division
University of California, Santa Barbara
Santa Barbara, CA

Bill Linder-Scholer
Cray Research, Inc.
Eagan, MN

Pat M. Loman
Shell Development Company
Westhollow Technology Center
Houston, TX

Carl D. McAulay
General Manager
Fred L. Hartley Research Center
Brea, CA

C. Gordon McCarty
Miles, Inc.
Mobay Road
Pittsburgh, PA

Kenneth O. McFadden
Vice Presdent, Research Division
W.R. Grace & Company
Columbia, MD

Otto Von Merring
Professor and Director
Center for Gerontological Studies
University of Florida
Gainesville, FL

Richard A. Milburn
Senior Vice President
Grumman International
Arlington, VA

J.C. Mihm
Senior Vice President
Phillips Petroleum Company
Bartlesville, OK

Steve Mitchell
Bioacoustics Research Program
Cornell Lab of Ornithology
Ithaca, NY

Nancy K. Morgan
Corporate Product Integrity
Mattel, Inc.
El Segundo, CA

Roger Morton
Business Unit Manager
Depth Imaging
Eastman Kodak Company
Rochester, NY

John H. Nelson
Vice President
Science and Technology
McCormick & Company, Inc.
Sparks, MD

Jack Nelson
Acting Dean
Office of the Dean
Temple University
Philadelphia, PA

James M. Pearson
Manager, Doctoral Recruitment
University Relations
Eastman Kodak Company
Rochester, NY

Timothy J. Pettibone
Dean, The Graduate School
New Mexico State University
Las Cruces, NM

Robert D. Phemister
Office of the Dean
College of Veterinary Medicine
Cornell University
Ithaca, NY

Henry C. Pitot
Professor of Onocology and Pathology
McArdle Laboratory for Cancer Research
Madison, WI

Gary W. Poehlein
Vice President for Interdisciplinary Programs
Georgia Institute of Technology
Atlanta, GA

Joseph A. Potenza
Provost
Office of the Provost and the Graduate School
Rutgers
New Brunswick, NJ

Frank L. Powell
Associate Professor of Medicine
University of San Diego
La Jolla, CA

J.W. Powers
Manager, Chemistry Laboratory
Packaging Products Group
Muncie, IN

Frederic Quan
Manager of Research Contracts
Corning, Inc.
Technology Sales and Licensing
Corning, NY

Mary Lee Seibert
Assoicate Provost and Dean of Graduate Studies
Ithaca College
Ithaca, NY

Raymond Seltzer
Ciba Additives
Ciba-Geigy Corporation
Ardsley, NY

Peter R. Schneider
Office of IBM Vice President, Development and Environmental Affairs
International Business Machines
Somers, NY

Leslie B. Sims
Dean
University of Iowa
Iowa City, IA

James A. Schafer
University of Alabama, Birmingham
Birmingham, AL

Mary Ellen Scott
Cleveland, OH

John T. Snow
Dean, College of Geosciences
American Meteorological Society
Boston, MA

David Sorensen
Executive Director
3M Coporate Technical Planning
and Coordination Department
St. Paul, MN

Gene Strull
Technology Consultant
Baltimore, MD

Susan Schwartz-Giblin
Professor Physiology
Vice Dean, Graduate School
Hahnemann University
Philadelphia, PA

Robert E. Thach
Dean, Graduate School of Arts and
Sciences
Washington University
St. Louis, MO

Roger Thies
College of Medicine
University of Oklahoma
Oklahoma City, OK

Steadman Upham
President, Western Association
of Graduate Schools
Graduate School
University of Oregon
Eugene, OR

Ed Wasserman
Central Research and Development
E.I. du Pont de Nemours
Wilmington, DE

Robert Wheeler
Department of Mathematical Sciences
Northern Illinois University
DeKalb, IL

Linda S. Wilson
President
Radcliffe College
Cambridge, MA

Chauncey Wood
Dean of Graduate Studies
McMaster University
Hamilton, Ontario, Canada

E

PANELISTS

A number of panels provided input to the committee deliberations on graduate education. These panelists, which represent faculty, graduate school deans, students, post-doctorates, women, minorities, and industry are listed below.

John A. Armstrong
South Salem, NY

Robert H. Atwell
President
American Council on Education
Washington, DC

Albert T. Bellino
Managing Director, College and University Relations, Recruiting and Retention, Internal Communications, and Advertising
Banker's Trust
New York, NY

Erich Bloch
Distinguished Fellow
Council on Competitiveness
Washington, DC

Joseph Bordogna
Assistant Director
Engineering Directorate
National Science Foundation
Arlington, VA

Dennis Brown
Provost and Senior Vice President, Academic Affairs
Drexel University
Philadelphia, PA

Sarita E. Brown
Principal Partner, Education Trust
American Association for Higher Education
Washington, DC

Leonard N. Carter, Jr.
Postdoctoral Fellow
Center for Space Physics
Boston University
Boston, MA

Paul Christiano
Provost
Carnegie Mellon University
Pittsburgh, PA

Edward E. David, Jr.
EED, Inc.
Bedminster, NJ

Frank A. DeCosta, III
Member, Technical Staff
Mitre Corporation
McLean, VA

Denice D. Denton
National Research Council Board on Engineering Education
Assistant Professor
University of Wisconsin
Washington, DC

Mildred S. Dresselhaus
Professor
Masssachusetts Institute of Technology
Cambridge, MA

Richard Fink
Amherst College
Amherst, MA

Gideon Fredier
Dean of Engineering
George Washington University
Washington, DC

Bob Frosch
Kennedy School of Business
Harvard University
Cambridge, MA

Mark Furth
Glaxo Research Institute
Research Triangle Park, NC

Charles A. Gray
Vice President, Technology
Cabot Corporation
Bilterica, MA

Paula Therese Hammond
Postdoctoral Associate
Harvard University
Cambridge, MA

Barry J. Hardy
Computer-Aided Molecular Design Group
Physical Chemistry Lab
Oxford University
Oxford, UK

Bradley T. Hargroves
Mitre Corporation
McLean, VA

Richard Herman
Dean of Science
University of Maryland
College Park, MD

Ruth Kirschstein
Deputy Director
National Institutes of Health
Bethesda, MD

Leonard Kline
Associate Director for Career Entry
Office of Personnel Management
Washington, DC

Joyce Ladner
Vice-President, Academic Affairs
Howard University
Washington, DC

Neal Lane
Director
National Science Foundation
Bethesda, MD

Jules B. Lapidus
President
Council of Graduate Schools
Washington, DC

Peter McGrath
President
National Association of State
Universities and Land Grant Colleges
Washington, DC

Feniosky Pena-Mora
Massachusetts Institute of Technology
Cambridge, MA

Thomas D. Pollard
Johns Hopkins University
School of Medicine
Baltimore, MD

Cornelius J. Pings
President
Association of American Universities
Washington, DC

Theodore Poehler
Vice-Provost of Research
Johns Hopkins University
Baltimore, MD

James L. Powell
Franklin Institute
Philadelphia, PA

Simon Ostrach
Wilbert J. Austin Distinguished Professor
of Engineering
Case Western Reserve University
National Academy of Engineering
Home Secretary

Roland Schmitt
Clifton Park, NY

Gerald M. Stancil
New Jersey Alternate
Teacher Certification Program
East Orange, NJ

Frank Wazan
Dean of Engineering
University of California, Los Angeles
Los Angeles, CA

Luther S. Williams
Assistant Director
Directorate for Education and
Human Resources
National Science Foundation
Washington, DC

Linda S. Wilson
President
Radcliffe College
Cambridge, MA

F

CALL FOR COMMENTS: SUMMARY OF RESPONSES

The committee solicited comments from more than 1,000 persons: graduate students, postdoctoral students, professors, university administrators, industry scientists and executives, and representatives of scientific societies. More than 100 responses were received, of which about half came from industry.

The committee noted several trends in the responses. There were general support for the current concept of PhD education (with a variety of suggestions for improvement, as outlined below), support for closer ties between the universities and industry, support for improved student counseling, and opposition to artificial limits on enrollments.

Although the call for comments was not a formal survey, we thought it would be useful to summarize the information gathered to indicate the diversity of views held by those with a stake in the success of our system of graduate education.

EMPLOYER EVALUATION OF PHD TRAINING

Overview

Industry and academic administrators generally responded favorably to the current concept of PhD training. Most comments affirmed US superiority in graduate education, but with the observation that there is always room for improvement. No substantial dissatisfaction was described. The following statement typifies the general sentiment: "We may see some specific difficulties in the relationship between academe and the profession it is intended to serve, but the structure itself is generally sound."

Preparation for Industry

However, some concerns were expressed about the level of additional education that is needed before recent graduates become fully participatory employees. Here is an example of a response from one major industrial employer that hires 150-400 advanced-degree people into its laboratories each year from many universities and in many disciplines:

> Even "the best of the crop" take anywhere from 6 months to 2 years to become good, productive industrial researchers. Most recent graduates, particularly those who have not summer-interned, do not have the foggiest idea of what industrial research is all about. Some even think that using or developing technology to do something useful is not research and if it is a product that makes a profit, is even slightly dishonorable.

Preparation for Teaching

Almost everyone expressed support for better preparation of graduate students for teaching. Respondents generally cited numerous reasons for this improvement, including the following:

- Students pay high tuition for instruction, and they deserve better. Courses taught via recitation do not help students learn or graduate students teach.
- It is wrong to assume that anyone working on a PhD is automatically able to teach.
- Students aiming at careers in academe should take formal teacher-training courses to learn pedagogy as well as they learn research.

For example, the following comment is from a graduate dean and provost:

> I have long been concerned about the teaching expectations of graduate students—all graduate students, not just in the sciences and engineering. How we can expect that an individual will intuit teaching skills is an amazement. While teaching is somewhat an art, there are many skills and techniques that need to be learned before an individual should be turned loose to teach a course. We do our graduate students no service, and certainly provide no service to the teachers, if

> we expect them to function in that capacity. ...They also need to be prepared to be academic advisors. It is not enough to walk into a class and conduct that experience. If graduate students are to be teachers, they need to know how to interact outside the classroom with undergraduate students, providing them the support that they should have during their undergraduate experience.

This is another:

> The universities are not doing any better in training PhDs for academe either. Except for the recent initiatives taken by some universities in giving them pointers on effective teaching, generally their training is in a narrow area of research and they are faced with on-the-job training.

Master's versus PhD Degrees

Expectations for those with master's degrees and PhDs are slightly different. Here is an overview from a major company:

> In the case of PhDs we are looking for high intelligence and creativity, the ability to originate and conduct independent research, a research background involving at least a solid thesis research experience, and the potential breadth of talent to move from one research field to another. The flexibility required by the latter point is important to us because we cannot hire new talent every time we wish to enter new research fields.
>
> We are also looking for excellent communication and interpersonal skills, so that with proper training they can develop into potential management candidates both in the research organization and in management positions in our operations. We have had a good track record in our research organization in supplying high-caliber talent to our operations.
>
> In the case of MS candidates, we are looking for the same kind of talents, except we do not expect experience in conducting research.

Changing Environment

Another consistent comment was on the changing environment—in both the industrial world and the academic world. The following comment is from the dean at a major graduate school:

> Graduates are not necessarily being well trained to participate in much of our high educational system as faculty: facilities for front-line research in sciences are not likely to get less costly. Not many colleges and universities will be able to afford the kinds of equipment required for faculty to make significant contributions to science in many areas. If this is true, most academic PhD positions will be in institutions which do not have essential facilities for what is viewed by these fields as cutting-edge research. Either the faculty in such institutions will have to carve out areas of research which don't rely on expensive equipment, or they will have to change their expectations of being significant players on the national and international science scene. It may be that there should be some effort devoted to training PhDs for research appropriate to those other institutions, either for enhancing their instructional roles or for providing them with realistic lines of research.

This is an industry perspective:

> In my judgment, educating and training students to do research as well as conducting basic research are still the primary objectives of graduate programs. However, it must be responsive to changing national policies and industrial needs.... I would agree that the American graduate system has been/is a great success. However, to ignore the indicators that show change is needed would be a mistake. Clearly, the challenge ahead is to retain the best of the system while making the changes that will strengthen the nation's outstanding research universities and make them more responsive to the nation's needs.

Yet another comment is the following:

> The days when a person could do a PhD thesis in surface thermodynamics (as I did) and reasonably expect to work in the field for a career are over—and I think will never return. One must be ready with the skills to change one's area of

> focus several times over a career. Most PhD education is training people in the exact opposite direction, and I think this needs to be changed promptly.

Broad versus Specialized Education

Respondents indicated some general concerns about the level of specialized training some graduates receive:

> Unfortunately, the training the graduates receive in universities is not directed to any specific career path. Most of the time, after some necessary training in their background, graduate students are pushed into narrow specialization. The consequence of such training is that many of them lack the breadth for work in industry. From what I have seen from the job offers received by our engineering students, they are successful with relatively less effort if their research topic and/or their assistantship experience is closely related to the prospective job description.

And they recommended a broader education for graduate students. One stated,

> we may place a new employee in a position which exploits any special expertise he/she may have gained in order to provide "a soft landing," but [he or she] will eventually be called upon to handle a wide range of problems that go far beyond the training received during the completion of the PhD.

A vice president of an applied-research organization wrote, "Everything else being equal, individuals with graduate training cutting across areas of engineering, management and business will turn into better candidates for employment than more narrowly educated specialists."

But one industry respondent warned, "It's a terrible idea to turn [PhDs] into some kind of generalists who don't know anything deeply."

Nevertheless, here is a comment from an international corporation:

> Why are industries such as ours not more accepting of PhDs with little or no experience? Because many fresh PhDs see their research area as their sole focus,

> at least for the immediate future. They generally tend to be very narrow. And, more important, they generally have no meaningful understanding of the *business* of business. Some might say that such understanding is the responsibility of business to provide. I say no. A highly trained scientist and engineer cannot be very effective if she/he has no knowledge at all of how a company is organized and why, lacks understanding about the principal staff and operating functions, is ignorant of the rudiments of accounting and finance, is unaware of product liability issues that directly affect product development, etc., etc. Industry cannot be expected to deliver such training and education in a short period of time. True, with years of experience working in industry such knowledge is slowly acquired—but it is an extremely inefficient transfer mechanism. Meanwhile, in the early years when the new technologist is working without awareness of these forces and boundary conditions, that person cannot be as effective as she/he otherwise might be. Careers are throttled.

And this is another:

> Most of the new PhDs that we hire seem to be relatively well prepared for careers in our organization. I would urge, however, that rather than move towards increasing specialization, which occurs very early in their training, the students should be given a broad array of courses in related areas early in their training. I have the impression that, also from day one in their program, students are now put into laboratories and given a research project so that they can develop the knowledge and skills in their specific area of activity to allow them to complete for grants in the future. However, it has been my observation that this type of training limits their ability to participate in multidisciplinary teams that are often necessary in the industrial setting.

CHANGING THE CURRENT GRADUATE EDUCATIONAL SYSTEM

How should this change the current graduate educational system? Respondents agreed that the apprenticeship system of learning research should be preserved. At the same time, many in industry expressed a desire for mentors to be more open to the changing needs of industry. Some professors and administrators favoring apprenticeship thought that their programs already produced the kind of flexibility that industry desires. For example, a dean noted, "We must not change [apprenticeship]... however, ...[it] can also produce a very narrow specialist who is confined and limited by departmental or disciplinary perspectives, even though

the obvious trend within the sciences is a breaking down of these barriers and a movement towards greater interdisciplinary perspective."

Expanded Experiences

There was also a general concern that students need to expand the experiences they have during graduate school:

> It is our general finding that US graduate schools successfully continue their tradition of producing well-educated scientists and engineers that are capable of making important contributions in their chosen fields. We also believe that the effectiveness of these graduates could be enhanced through practical ("hands-on") experiences/traineeships, functioning as a member of a (multidisciplinary) team, strengthened interpersonal skills, ability to communicate clearly the purpose (including the "strategic" value and relevance of the activity in question), and substantial knowledge of the business environment/culture (including project management fundamentals, time/effort/budget deliverables, sensitivity to human resource concerns, safety, intellectual property, etc.).

Skill Expansion

In general, employers do not feel that the current level of education is sufficient in providing the following skills and abilities for the people that they are interested in employing:

- Communication skills (including teaching and mentoring abilities for academic positions).
- Appreciation for applied problems (particularly in an industrial setting).
- Teamwork (especially in interdisciplinary settings).

For example:

> We look for top-notch technical skills and some evidence of ability to "reduce to practice" the technologies the candidate has been involved in. If we look at new

> graduates, we look for curiosity about and an appreciation for practical applications of science. As we move away from independent, stand-alone research, and toward more team projects, we screen and hire candidates based on their ability to work in teams, to lead collaborations and teams in an effective way. Skills like project management, leadership, planning and organizing, interpersonal skills, adaptability, negotiation, written and oral communication and solid computer knowledge/utilization and critical for an industrial R&D scientist/engineer. If you walk on water technically but can't or won't explain or promote your ideas and your science, you won't get hired. If you do get hired, your career will stall.

GRADUATE-EDUCATION ISSUES

Respondents were also asked about a number of key graduate-education issues.

Limiting Enrollments

Industry and administrators seemed to agreed that limiting enrollments was the job of market forces; professors disagreed. As a justification of limitations, they often cited an internal necessity, such as resource or space limitations, rather than a desire to affect the overall market. An industry respondent wrote, "Limiting enrollments is a drastic action to take since the law of supply and demand will usually bring about a correction, albeit several years out of phase. In a few particular disciplines, e.g., chemical engineering, limiting enrollment at the PhD level may need to be seriously considered." A dean wrote:

> I would be hard pressed to argue that the world can ever have too many persons trained in the methods of inquiry.... The experience of students graduating with PhDs in the humanities in the 1970s showed us that good minds well trained will find a way to make a difference in places that didn't even know they needed or wanted PhD holders. Such may be the case with science and engineering....

This is from a graduate adviser:

> I am skeptical about the utility of attempts to manage enrollment; it is simply too hard to predict what is appropriate, let alone optimal. We at [our university] have been asked to control graduate enrollment, but I suspect that the real controls are still market mechanisms.

Time to Degree

There was nearly uniform agreement that the time to degree completion or initial employment is becoming longer. Many respondents favored shortening the time to degree, but others noted that adding teacher training, minor degrees, and other projects for graduate students could add to the time to degree and make it less easy to identify. A dean remarked, "It is not clear that 7 to 12 years of graduate work is either required or appropriate for most positions in business or industry."

National Goals

A question about national goals for graduate education drew a common response: there are none. A common impression was that graduate education, though considered the "best in the world," is generally rudderless without the external stimuli of the type provided, for example, by Sputnik and the Cold War. A professor at the New Jersey Institute of Technology wrote, "The problem is one of national focus and goals and not the education to support them. There does not seem to be a unifying technological endeavor or an idealized goal with technological underpinnings, to inspire our students and engender popular support."

Conclusion

In conclusion, the themes of the anecdotal information collected via the committee's call for comments indicates that although employers are generally pleased with the result of US graduate education, they have some specific concerns as to the breadth, versatility, and skill development in that education. Furthermore, they are concerned that the graduate education

system as it exists today—although acceptable for the past employment world—is less and less acceptable in today's more global world.

INTERESTING IDEAS

Many interesting ideas were suggested by the respondents, and they are summarized below. The committee did not have the resources to evaluate all suggestions fully, so it presents them here for further thought and discussion. They are divided into three categories: career preparation, information needs, and funding. Each is summarized as action items and advice for universities, industry, students, and the federal government.

After the responses were received, the committee decided to conduct a separate survey on information needs; a summary of the survey results is provided in Appendix G.

Career Preparation

Universities should

- Initiate more collaborative arrangements with employers. '
- Initiate more opportunities for research programs in association with industry.
- Eliminate tenure so that diverse teams of full-time and adjunct faculty can work together.
- Elevate manufacturing to the same level as the arts.
- Enrich the science and engineering curriculum to include training in interpersonal communication, technical writing, team skills, business-process management, accounting, and competitive assessment.
- Seek industrial appointments and sabbaticals for their faculty.
- Require that graduate students who teach be supervised on their first assignment by persons who can give them advice feedback on style and method.
- Help students to complete their education expeditiously.

- Continue to train research scientists of the highest caliber.
- Replace half the PhD candidates' course load for the first year with some form of apprenticeship.

Industry should

- Provide more internships in which academic fundamentals can be applied in real-world problems.
- Seek persons who have the ability to conceptualize, apply, develop, and continuously improve processes or products that can be sold at a profit.
- Support more "centers of excellence" to eliminate duplication of effort.

Industry is looking for

- Persons trained and specialized in the traditional scientific disciplines who can integrate skills with science.
- Persons with good writing skills.
- University-trained graduate students who are knowledgeable about safety, quality, statistics, and communication and who have good interpersonal skills.
- Highly technical employees and general managers.
- Persons who can negotiate with, work with, and lead others on a team (broadly trained scientists).
- Persons who can originate and conduct independent research.

Students should

- Take courses dealing with "applied interdisciplinarianism."
- Take a minor and more courses outside their specialties.
- Submit a proposal detailing the plans for their primary research efforts.

Information Needs

Universities should

- Collect benchmarking data to monitor the quality of approved programs and to try to satisfy hiring patterns of employers who regularly draw from particular program.
- Improve student counseling so that those planning PhD in the basic sciences understand, in advance, what the government gauges as appropriate for a PGY1 PhD salary.

- Assess the needs for professors and doctoral-level industrial personnel, translate the results of this assessment into a set of goals, and design strategies to achieve the goals.
- Offer students some comment about job prospects and frank cautions where job prospects are poor, as in physics. Disclosure of programs' completion rates and completion times would help prospective students to make informed choices.

Funding

Universities should

- Reduce their size by establishing quality criteria for doctoral programs.
- Refocus their funds through wider use of fellowships than of institutional grants.
- Provide adequate preparation of scientist by using methods that do not depend on external funding sources. Dependence of doctorates in the sciences on external (federal) funding makes programs vulnerable.
- Stop defending lower quality programs--some institutions are better prepared to deliver first-class PhD education.
- Bring the cost of graduate research assistants in line with the cost of laboratory technicians.
- Improve teaching by establishing a policy that senior graduate students can apply for federal grants to supplement their support and in exchange teach graduate courses.

The federal government should

- Grant more fellowships directly to students, which would separate financial support from the research process.
- Set guidelines so that no professor can be funded for more than five research assistantships; this would curtail empire building and encourage collaboration.
- Create a category of funding open to all faculty members, regardless of seniority.
- Restrict the number of foreign students on federal grants; this would force institutions to look inward for their supply of graduate students and make more of an effort to coach them.
- Levy a surtax on employment of foreign graduate students, i.e., require more money for scholarship funds for each foreign student used.

- Eliminate NSF graduate fellowships and redirect the money to research funding. Their fellowships are outdated and send the erroneous message to students that the nation needs more scientists.
- Provide, with state governments, financial support for advanced graduate students to visit public universities and liberal-arts colleges for one semester as professorial interns.

Industry should

- Help to change the science and engineering culture by setting aside a small amount of R&D money for internships for graduate students.
- Cooperate with funding agencies in preparing and reviewing requests for proposals without requiring rights to intellectual property as long as there is no direct monetary support.

G

Summary of Responses to Survey on Information Needs

In gathering data for this study, the committee asked scientists and engineers who have recently completed graduate degrees to describe the information they feel is necessary for students to make sound decisions about graduate education. We asked three questions about each of several topics:

- "What do you know today that you wish you knew when you were a student?"
- "What are the top 8-10 key areas that students need to know about in order to make academic and career decisions?"
- "When do you think students need this information?"

We found the responses to the questions interesting enough to warrant the detailed summary offered below. One surprising result was that students did not desire career *placement* information as much as career *guidance* information. They also have a strong interest in information on the graduate education process itself. As a result, the committee may consider developing a document to provide such guidance.

On the topic of the ***graduate education process***, students need to know more about:

- The focus of graduate education. In particular, students should use research to "train the mind" rather than simply to acquire techniques used in the "real world."
- The chronology of a PhD program, and what is required at each step.

- The differences between careers in specific subfields (e.g., astrophysics, plasma physics, particle physics). Which are the 'successful' fields of research? Which offer the best job opportunities?
- The extent to which one should narrowly specialize within a particular subfield. For some positions (e.g., post-doctoral positions) and fields, specialization is considered an asset. For others (e.g., industry positions) it is considered a liability.
- Alternative areas of study beyond pure science (students need to be assured that alternative areas are worthy).
- Maturity as an asset in graduate school. Although the "traditional" path is to enter graduate school directly from a bachelor's degree program, a year or two of experience allows the student to mature.
- The political nature of science. Graduate school is more than classes. It is: choosing an adviser, defining a thesis project, giving seminars on your subject, networking, and many more activities which require "people skills." Students need to understand in detail how advisers have influence over a student's future.
- The importance of research: Students should know that they will be evaluated in terms of their research productivity as a graduate student and as a postdoctorate.
- Developing a successful grant may take as much effort as completing a master's thesis.
- The importance of student funding as a criterion for judging the quality level of a program.
- The importance of the difference between state universities and private universities in regard to their treatment of foreign students.
- Alternatives to an American PhD that can be pursued abroad. For example, in the British system, a graduate degree requires only a thesis (no classwork) and has a typical time-to-degree of 3 years.

CAREER GUIDANCE INFORMATION

- The importance of working in a field before making the decision to enter that field. For example, bright young college students who become technicians in an area learn a great deal about professional jobs in that area as well as inside information on how the field operates.
- The importance of the university one attends and the standing of one's faculty adviser (the "prestige factor") if one plans to go into academia or research.
- The difficulty of obtaining and retaining tenured faculty positions.
- The typical career structure in science and the range of differences, versus stereotypes portrayed in the media. Some jobs are "high-paying and wonderful"; others are "slave labor."

- The potential to successfully advance in a career as an academic or industrial scientist. What are the attrition rates between graduate school and tenure?
- The sectors that employ scientists in given fields and subfields, and the average age of scientists in those areas.
- A realistic comparison between careers in science and careers requiring other advanced degrees, such as an M.D., J.D., or MBA.
- The variance in salaries and competition levels among fields and subfields.
- The importance of seeking career information from academics, industrial scientists, and others with nonacademic careers instead of relying only on universities to provide such information.
- Acknowledgement that the employment market for scientists and engineers upon graduation is unpredictable. Many students assume that positions will be available when needed. There are no such guarantees.
- Students would benefit from knowing how a career evolves beyond the 'first job'. Departments could maintain a list of the career paths of their graduates. (Descriptions of career paths could remain anonymous.)
- An overview of the working world in a given field. What are the opportunities, expectations, pressures, and rewards; how do employers view and treat their employees.
- Quality information and discussion forums for young scientists made available on the Internet to balance the advice they receive from senior scientists.
- The counterintuitive concept that earning a PhD is considered by some to "overqualify" a person for many types of positions (e.g., performing technical work that does not require research skills). Sometimes one is more employable with a bachelor's or master's degree than with a PhD.
- Some potential employers, such as the National Institute of Standards and Technology, do not generally hire permanent employees through normal procedures. One must first win a very prestigious award - the National Research Council post-doctoral fellowship - before being considered for permanent employment.
- Most industry employers do not advertise openings for scientists and engineers at the PhD level.

KEY VARIABLES

To the question "What are the top 8-10 key variables that students need access to in order to make graduate education decisions?" there was no unanimity of responses. The most common answers were:

- A realistic view and recent history of the job market;

- An understanding of the funding situation in science and engineering as a function of scientific discipline, age, race, sex, geography, and time since degree.

The remaining responses, as with the first question, fell under the two broad categories of program information and employment information.

PROGRAM INFORMATION

(Note: All of the following items will vary by field and subfield.)

- Funding profiles and researcher population growth.
- Length of time-to-degree and time to first permanent position.
- Rate of retention from entry into the graduate program to degree completion.
- Frank assessments, 1: Opinions about available schools (including information on quality, cost, location, and research facilities) from students' points of view.
- Frank assessments, 1A: Experiences of recently graduated young scientists.
- Frank assessments, 2: Independent opinions about faculty advisers.
- Frank assessments, 2A: A list of seasoned, knowledgeable, accessible senior investigators with mentoring skills. No printed materials can substitute for the experience they can share or the vision they can impart.
- Required proficiency level in the necessary academic skills demanded by the profession (e.g., how proficient in math must a physics major be?).
- Minimum acceptable GRE scores and GPA.
- How much time is need to acquire the PhD skills.
- The ability to minor in a discipline remote from the major discipline.
- The amount of salary and financial aid that can be expected.
- Living costs for graduate education as a function of geography.
- The availability of a career placement system for science and engineering graduate students.
- History-of-science publications that would help students understand the development of various fields.

EMPLOYMENT INFORMATION

Respondents consider this area very important - especially because advisers may not have a full understanding of potential employment settings, especially nonacademic settings. Students need to know more about the following, by field:

- Placement record of various programs.
- Alternative career paths at various levels of education, including B.S. and M.S. levels.
- Realistic notions of career demands (time, financial, personal) in various areas of study, versus the intellectual rewards.
- Frank assessments of what it is like to work in a given field. Preconceptions are often misconceptions. For example, do undergraduates realize how much writing scientists do? Do they know how much time, energy and skill must be devoted to obtaining research grants? Do they have any idea of the day-to-day frustrations and rewards of working in industry versus academia?
- Starting salaries.
- Main source of employment. If it is an industry, what is the long-term prognosis for the health of that industry?
- Employment prospects after 1, 2, 5, 10, 20 years.
- Average hours worked per week.
- How well does one's desired standard of living match the typical income level of the profession?
- How many of an institution's graduates succeed in their field of study?
- Rate of employment turnover for recent graduates.
- How many jobs are there per job-seeker? (In today's tight job market, several correspondents on the Young Scientists' Network have used the estimate of one job for every six science and engineering graduates.)
- Qualities and skills valued by industrial employers.
- Grant-related opportunities available to young scientists as both graduate students and postdoctorates. How many years will they have to wait to gain independence?

The third question asked was, "When do you think students need this information? Do they need it at one stage or at many stages? Which information is needed at what stages?" The responses could be summarized as follows:

> "The information needs to be available at many stages. People come gradually to new understandings and new questions, and reassess their progress continually. So the information needs to be available and findable when they're ready for it."

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SCIENCE

Producing the Finest Scientists and Engineers for the 21st Century

Mary Lowe Good and Neal F. Lane

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Producing the Finest Scientists and Engineers for the 21st Century

Mary Lowe Good and Neal F. Lane

Science in the National Interest (*1*), the recent White House report on science policy, is receiving well-deserved praise for providing the vision needed to guide federal investments in basic science, mathematics, and engineering. The report in effect challenges the research and education enterprise to increase its contribution to improving the nation's health, economic prosperity, national security, environmental responsibility, and quality of life.

One of the central goals presented in the report is to "produce the finest scientists and engineers for the 21st Century." This goal reminds us that scientifically and technologically trained people are an invaluable national asset—a foundation of strength that enables the nation to pursue a great variety of opportunities. Professional scientists and engineers anchor the scientific and technological work force and are indispensable to promoting growth and innovation throughout our economy. As the report emphasizes, "Our principal resource for maintaining leadership in fundamental science and engineering and for capitalizing on its advances is our talent pool of well-educated scientists and engineers. . . Because training scientists is a long process, we cannot quickly overcome shortfalls in trained personnel in some areas and should not react precipitously in allocating our training support" (*2*).

Therefore, to continue serving the nation in this way, the academic research and education enterprise faces one basic question: What is required to produce the finest scientists and engineers for the 21st century? The answer is far from obvious—for it depends entirely on the definition of the term "finest." On the one hand, many would say that we are already producing the finest scientists and engineers, provided "finest" is defined to mean superbly capable and highly specialized students prepared to carry on in the traditions of academic basic research. On the other hand, if one adopts a definition of "finest" that includes such attributes as versatility, a willingness to pursue a broad range of career options, an adequate reflection of the diversity of our society, and the ability to work in groups and integrate science and technology to meet the needs of industry and other sectors, then there is virtual consensus that the current system leaves room for improvement.

The challenge is to reconcile these two definitions of "finest"—preserving the qualities and capabilities instilled by the current system, while drawing upon all parts of society's talent base and readying students for the work force of the 21st century. This is a challenge that runs to the core of how best to secure a bright and sustainable future for the academic research and education enterprise—a future that preserves and enhances the tradition of excellence and achievement that has served the nation well for decades, and, at the same time, ensures continued strong public support for science and advanced education in the post–Cold War era.

Long-term success in this endeavor is not simply a matter of inventing a few new programs or selectively tinkering with the labor market. Rather, producing the finest scientists and engineers for the 21st century requires revisiting and reassessing many of the long-standing practices and traditions of research and graduate education in science and engineering.

Specifically, we recommend a policy framework that focuses on three key points: (i) Teaching and learning must be reinvigorated as the primary mission of academic institutions. (ii) Policies governing federal support for academic research must explicitly recognize the importance of such support to the education and training of scientists and engineers. (iii) Graduate education in science and engineering must better reflect the many profound changes in the economy generally and in the labor market for professional scientists and engineers specifically.

In this Policy Forum, we expand on these three points and outline ways that they can provide a cornerstone for future actions at the national level, within institutions, and by individual researchers and educators. The actions we recommend revolve around one basic principle: providing science and engineering graduate students, especially at the Ph.D. level, with a broad range of experiences that prepare them for rewarding careers both inside and outside of academe.

Furthermore, while these three points focus specifically on graduate education, they also apply to issues at the undergraduate and precollege level. Reaching the goal of producing the finest scientists and engineers for the 21st century requires improving education at all levels and cultivating the talents of all students in our society. We believe that the framework outlined here—by highlighting the natural connections between teaching and research—will improve linkages between graduate education and undergraduate teaching as well as position the academic enterprise to increase its contribution to mathematics and science education at the precollege level.

Academic Institutions: Refocusing on Teaching and Learning

The nation's colleges and universities are assuming (and being expected to assume) an ever-increasing set of roles and responsibilities. Even just a partial list of these new or expanded responsibilities would include serving as a think tank, a government and corporate research arm, a small business incubator, a technology-transfer mechanism, a promoter of economic development, and numerous other functions in addition to the core teaching responsibilities of the institution. These responsibilities reflect increased recognition for the contribution research universities can make to regional and national economic growth, as well as the value of linking research, education, and training to nonacademic settings.

What is most important, therefore, is that institutions pursue (and be allowed to pursue) these activities in ways that enhance learning experiences for students and further the teaching mission of higher education. This point was underscored by the Industrial Research Institute (IRI) in its 1993 Statement on Strengthening Industry-University Interactions: "The Institute endorses the premise that the top priority of universities should be to educate their students. Basic research in universities and interaction with the private sector can support and strengthen this educational priority" (*3*).

Academia's partners in these activities—notably government and industry—should adopt a holistic perspective of the academic enterprise that fosters the processes of teaching and learning. The IRI statement signals such a commitment on the part of industry. *Science in the National Interest* outlines a similar commitment on the part of the federal government. The report's primary thesis is that "Science is an endless and sustainable resource with extraordinary dividends" (*4*). Government policies and programs should view the academic enterprise as a whole and cultivate it as a national asset. This in turn would establish a framework for future partnerships that would allow teaching to flourish in conjunction with research and other activities.

M. L. Good is Undersecretary for Technology, U.S. Department of Commerce, Washington, DC 20230, USA. N. F. Lane is Director, U.S. National Science Foundation, Arlington, VA 22230, USA. This article is in the public domain.

Support for Fundamental Research: Importance to Education and Training

Our next point also requires taking a new look at the relationship between the federal government and academic institutions. The federal government's reasons for supporting basic research at academic institutions have long included both ensuring a continuous flow of new knowledge and educating future scientists and engineers through participation in research at the frontiers of knowledge.

Today, research funding serves as the predominant means of federal support for graduate students in science and engineering. In fact, the mechanisms used by the federal government to support science and engineering graduate students have shifted markedly toward research assistantships over the past two decades. In 1975 graduate students at doctoral institutions who received their primary support from the federal government were almost as likely to have fellowships or traineeships as research assistantships (41% compared with 49%). Today they are more than twice as likely to receive support through research assistantships: in 1992, 65% of students enrolled in doctorate programs who received federal support relied on research assistantships for their primary support, compared with 27% who relied primarily on fellowships or traineeships (5).

The dominance of the research assistantship as a form of student support certainly has its pluses and minuses. There can be no doubt as to the intrinsic value of participation in research as a teaching tool. By working on first-rate, merit-reviewed projects, students receive the ideal form of on-the-job training with the latest research methods and instruments. The downside, however, is that, when compared with fellowships and traineeships, research assistantships are a very imprecise instrument for producing human resources for science and engineering. First, because students are in effect bound to their faculty mentors for financial support, they have less flexibility to pursue innovative learning experiences, such as participating in collaborative research with private corporations. In addition, research funding could play a larger strategic role in developing human resources for science and technology, particularly in attracting and cultivating more students from groups in the U.S. population that have traditionally been underrepresented in science and engineering. This has taken on added importance now that the majority of new entrants to the workforce are women and minorities.

A key policy recommendation presented in *Science in the National Interest* directly addresses this issue. The report directs the National Science and Technology Council to "produce a human resources development policy for sustaining excellence and promoting diversity in the science and technology work force" (6). It almost goes without saying that a key tenet of this policy must be to recognize the vital link between research and graduate education—the defining strength of our academic research and education enterprise.

Other positive steps are already in the works, thanks to the current priorities in science and technology policy. First, the emphasis on connecting fundamental research to national priorities gives graduate students more opportunities to participate in interdisciplinary research that is relevant to pressing societal concerns. Students thereby gain increased experience working in multidisciplinary and often multisectoral groups on projects designed to highlight connections between new knowledge and the health and well-being of society. In this same way, industry-university cooperative activities are also vital. These activities yield multiple benefits. By working directly with scientists and engineers from industry, students gain new awareness of needs and opportunities in the private sector. At the same time, the companies are given a window on leading edge research and emerging technologies as well as the abilities of possible future employees.

Graduate Education and Changing Realities

The first two points we have made in this commentary require increased leadership principally on the part of academic institutions, the federal government, and research-intensive industries. This third point focuses more directly on individual faculty members and the guidance they provide to science and engineering graduate students. Our message is a simple one: Everyone who teaches and counsels future scientists and engineers must give careful consideration to the many profound changes in career paths in these fields and in the economy and work force generally.

Contrary to what is often reported on the issue, the changes in the academic job market have been under way for some time. While the nation will always need outstanding scientists and engineers to teach in colleges and universities, the share of Ph.D.-level scientists and engineers employed at academic institutions has been steadily declining for over two decades, and today roughly half of all doctorate level scientists and engineers work outside academe (7). This in itself necessitates some rethinking of the purposes of doctoral training.

More sudden changes have occurred in the sectors of the economy that traditionally have employed large numbers of Ph.D.-level scientists and engineers. These changes have been widely reported and discussed. As the National Science Board's most recent version of Science and Engineering Indicators puts it: "... in the early 1990s, the recession, defense-related spending cutbacks, reduced research and development budgets, and industry downsizing all took their toll on [science and engineering] employment" (8). With national laboratories being refocused and industry's research and development laboratories being restructured and often attached to corporate business units, newly minted Ph.D.'s more and more are facing the prospect of exploring nontraditional career paths.

This places a new set of responsibilities on faculty to help students prepare for and seek a wider variety of career opportunities, and the reward system at academic institutions should take these responsibilities into account. In the end, it falls to individual faculty members to help their students recognize the diverse set of rewarding careers available to professional scientists and engineers.

Consider, for example, two areas where young scientists and engineers could make an immense contribution to the nation, yet all indications are that these areas remain largely unexplored. Teaching is one area where people who can communicate the excitement of science and engineering can make a major contribution. National Academy of Sciences President Bruce Alberts among others has sounded this call (while also noting that graduate students expressing such interests receive little support from their faculty advisers) (9).

A second set of promising and largely unexplored opportunities may reside in the small business sector. The National Research Council (NRC) recently surveyed the small manufacturers that have sought advice from Manufacturing Extension Centers operated by the National Institute of Standards and Technology. The NRC found that one of the principal barriers to the competitiveness of these firms is their lack of awareness of "best manufacturing practices, innovative application of new technologies, and fresh approaches to improved production efficiency" (10). This suggests that with improved training in areas such as the management of technology and the business environment, recent science and engineering graduates would bring experience needed to help make these firms more competitive in the global marketplace. This adds up to a win-win situation for the individual students and the firms, as well as for the academic enterprise and the nation as a whole.

Conclusion

It has been said that the greatest teachers always point beyond themselves. This is what separates teaching from other professions—the hope and expectation that our students will surpass our own achievements. This standard might be best exemplified by J. J. Thomson, the Nobel Prize–winning physicist credited with discovering the electron. Eighty years ago, the model of the atom he developed (commonly known as the "plum pudding" model) was displaced by the nuclear model developed by his former student, Ernest Rutherford. (In total, seven of Thomson's students, including Rutherford, received the Nobel Prize—an amazing legacy by any criterion.)

Today's science and engineering graduates face a challenge of a different dimension—pursuing intellectual and professional horizons that surpass the conventions known for generations. For the individuals, institutions, and government agencies that shape policies for graduate education and research, this requires changing and updating many long-standing practices. The three points we outlined—reinvigorating the teaching and learning mission of higher education, fostering a more strategic link between research funding and graduate education, and recognizing the changed career paths awaiting future scientists and engineers—provide touchstones for progress in this time of change. By embracing these new directions while preserving its fundamental strengths, the academic enterprise, working in partnership with government and industry, should have no trouble producing the finest scientists and engineers for the 21st century.

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NATIONAL SCIENCE FOUNDATION
4201 WILSON BOULEVARD
ARLINGTON, VIRGINIA 22230

October 20, 1995

OFFICE OF THE
DIRECTOR

Honorable Steve Schiff
Chairman
Subcommittee on Basic Research
Committee on Science
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

During the July 13, 1995, Basic Research Subcommittee hearing on graduate education you requested plans that the National Science Foundation (NSF) had for responding to the recommendations of the COSEPUP report. I am pleased to provide this update of NSF's ongoing efforts to ensure that the graduate education of scientists, mathematicians, and engineers is responsive to national needs.

NSF has taken a number of steps in recent years to improve science and engineering graduate education, several of which are referenced in the COSEPUP Report, ***Reshaping the Graduate Education of Scientists and Engineers***. For example, our Grant Opportunities for Academic Liaison with Industry (GOALI) program, which started in the Engineering Directorate, has been expanded across the Foundation. One of the objectives of this program is to provide graduate students with broader experiences in industry to enhance their career options and opportunities.

NSF has also supported a variety of innovative research centers which create partnerships between NSF, academic institutions, industry, states, and other Federal agencies. One of the underlying considerations in developing research centers is to provide points of articulation between universities and the private sector so that students have an opportunity to work on problems that are basic in nature, but also of interest to industry. In 1994, it is estimated that over 450 academic institutions participated in NSF center activities. In addition, more than 1800 non-academic partners supplied nearly $300 million to these centers, providing $3 for every $2 contributed by NSF.

A principal recommendation of the COSEPUP report was to "allow students to gain a wider variety of academic and other career skills." Centers provide a very effective model for integrating research, education, and practical experience. Other models for broadening career horizons of graduate students, frequently drawing on existing NSF programs, were mentioned in the COSEPUP report. We are continuously seeking better ways to ensure that talented students attracted to careers in science and engineering have access to graduate training that meets broader career needs.

A second set of recommendations in the COSEPUP report centered on providing prospective graduate students with better career information and guidance. NSF serves as the central clearinghouse for data on the nation's scientific and engineering resources. The challenge has been to provide this information in a timely fashion to policy makers, researchers, career counselors, and students who could factor this information into their planning for the future.

The COSEPUP report also addressed the need for improved coverage, timeliness, and analysis of data on the education and employment of scientists and engineers. We have in recent years significantly enriched the content of our surveys based on the recommendations from the National Research Council's Committee on National Statistics. While many of these new data were not available at the time the COSEPUP report was written, they are now or soon will be.

We recognize the importance of timeliness in making survey results available and are working with the National Research Council to address this issue. For example, while these surveys are large and complex, we are looking into disseminating preliminary data from these surveys, as well as other timely indicators of general labor market conditions, for scientists and engineers.

To ensure that our statistical products meet our customers' needs, NSF staff has interviewed about 50 key users of NSF data during the past two years. A larger user survey is planned for 1996, giving us additional guidance in setting priorities for data collection and analysis.

NSF has greatly improved electronic dissemination of its data. Virtually all of the data and reports of our Science Resources Studies Division are available on the World Wide Web.

The COSEPUP report closes by noting the need for a continued discussion of the issues related to graduate-level human resources. Although improved data collection, analysis, and dissemination are important steps in providing information useful for policy makers and students interested in careers in science and engineering, fundamental changes within the current graduate education system must also be considered.

In this regard, a Task Force on Graduate and Postdoctoral Education was established by the National Science Board (NSB) at its June 22, 1995, meeting. The task force is composed of eight members of the NSB and is charged with examining the mix of support provided by NSF for graduate and postdoctoral students and how various modes of support affect their experience and preparation.

Thank you again for the opportunity to provide you with an update of NSF activities relating to graduate education in science and engineering as discussed in the COSEPUP report. I appreciate the Subcommittee's interest in this topic and I look forward to continuing our efforts to improve graduate education.

Sincerely,

Neal Lane

Neal Lane
Director

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

National Institutes of Health
Bethesda, Maryland 20892

OCT 30 1995

The Honorable Steven H. Schiff
Chairman, Subcommittee on Basic Research
Committee on Science
House of Representatives
Washington, D.C. 20515-6301

Dear Mr. Schiff:

This is a follow-up to the July 13 hearing on graduate education held by your Subcommittee and in response to your subsequent letter of July 25 regarding the National Institutes of Health (NIH) graduate training programs.

The NIH Research Training Office assembled a Working Group composed of Institute staff to assess the NIH training programs in relation to the recommendations expressed in the National Academy of Sciences' (NAS) Report: Reshaping the Graduate Education of Scientists and Engineers. I am enclosing the NIH Plan for implementing these recommendations. It describes the principal attributes of the current NIH training program and provides information regarding our position in the future. The document also addresses your question regarding the appropriate mix of Federal support for graduate training grants, fellowships, and research applications.

I appreciate this opportunity to add to my testimony and would be pleased to discuss these issues with you in more detail at your convenience.

Sincerely,

Harold Varmus

Harold Varmus, M.D.
Director

Enclosure

NIH Plan for Implementing
the
Recommendations in Reshaping The Graduate Education of Scientists and Engineers[1]

This document describes the recommendations for graduate institutions and Federal agencies in the COSEPUP report, Reshaping the Graduate Education of Scientists and Engineers. It also indicates current NIH compliance with the recommendations or future plans to implement the recommendations. This document was prepared by a small work group[2] as a follow-up to Dr. Harold Varmus' July 13 testimony before the House Science Subcommittee on Basic Research in response to a request from Representative Steven Schiff (R-NH), Subcommittee Chair and Representative Pete Geren (D-TX), Ranking Minority Member. In addition to the recommendations from the report, this document addresses an additional question submitted in a letter by Representative Schiff, dated July 25, regarding the appropriate mix of Federal support for graduate training grants, fellowships and research assistantships.

The recommendations from the COSEPUP report and the subsequent question from the Chairman of the Basic Research Subcommittee appear in text boxes.

Offer a Broader Range of Academic Options:

- To produce more versatile scientists and engineers, graduate programs should provide options that allow students to gain a wider variety of skills.
- To foster versatility, government and other agents of financial assistance for graduate students should adjust their support mechanisms to include new education/training grants to institutions and departments.
- In implementing changes to promote versatility, care must be taken not to compromise other important objectives. For example:
  - Maintain local initiative
  - Maintain excellence in research
  - Control time to degree
  - Attract women and minority-group members

The NIH has used a system of research training grants to support graduate education in the biological sciences since 1958. The extensive experience in managing this program has provided the opportunity for considerable refinement of this support

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[1]Report from the Committee on Science, Engineering and Public Policy (COSEPUP) of the National Academy of Sciences (NAS) was published in 1995 and is available from National Academy Press.

[2]Ms. Lacey Durham, NCRR; Dr. Ronald Geller, NHLBI; Dr. Danuta Krotoski, NICHD; Dr. Charlotte McCutchen, NINDS; Dr. John Norvell, NIGMS; Dr. Walter Schaffer, OD; Dr. Carolyn Strete, NIMH. All questions should be directed to Dr. Walter Schaffer in the Research Training Office at 301-496-9743.

mechanism, which is now carried out as directed by Section 487 of the Public Health Service Act. In fiscal year 1995, NIH training grants supported approximately 6,000 graduate students in programs leading to the Ph.D. degree. An additional 850 students received support in programs leading to the combined M.D./Ph.D. degree. In nearly all respects, these NIH training grants are identical to the "education/training grants" recommended by COSEPUP for all Federal agencies. Training grants encourage institutions to assume local initiative in the design and implementation of their graduate training programs; to maintain excellence in both education and research; to control the time to degree; and to devise active strategies for recruitment of underrepresented minorities and women into research careers.

Part of the reason NIH training grants have been successful relates to the review process. Each of these grants must be reviewed by a committee of peers at least every five years. At the time of competition, the applicant institution must demonstrate that former trainees have been successful in establishing productive careers. The institution, therefore, is strongly encouraged to select the best students from a pool of high quality applicants for their training program and to design a course of research and study that will lead to a successful career. The content and the structure of the program varies from institution to institution but is tailored to fit the available resources and the specific career needs of that particular discipline. Reviewers carefully examine the objectives and the design of the training program and the caliber of the preceptors. The training record of the program is extensively documented in the application to permit a determination of past success which is then used as a predictor of future placement of trainees in appropriate positions. The stringency of the review process, which in some cases includes on-site visits, ensures that training grants will continue to be valued by the biomedical and behavioral academic community as evidence of a high quality graduate training program.

The NIH approach to graduate training is already consistent with the recommendations in COSEPUP report. As evidence of this fact, we have found that students supported by training grants complete their degree requirements more quickly and are more likely to engage in research activities upon completion of their training than are their counterparts without NIH training grant support. Typical NIH supported graduate trainees receive between 2 and 3 years of training grant support in a broad multidisciplinary environment. During this period, students have an opportunity to develop a sound understanding of the basic scientific principles they will need as researchers. They also have an opportunity to rotate through a number of different laboratories as a way of learning a variety of experimental approaches to research problems. At the end of this period, students take qualifying examinations and then move into a period of intensive research in preparation for their doctoral dissertation. In most cases, students are supported as research assistants during the dissertation phase of their graduate studies. Throughout graduate school, students supported by the training grant are monitored by a faculty committee to ensure that the training experience is appropriate for evolving research needs and that the doctorate will be

earned within a reasonable period of time.

Training grants offer a number of potential advantages over less formalized training programs. Trainees are often encouraged to teach a course and some are permitted to have research training experiences away from their parent institution. These experiences sometimes include "internships" in an industrial research setting. With an NIH training grant comes the requirement to provide all trainees with a course in the responsible conduct of science, which includes instruction in responsible authorship, policies for handling misconduct in science, policies regarding the use of experimental subjects, data management, and conflict of interest. The NIH also requires institutions with training grants to actively recruit trainees from underrepresented racial and ethnic groups. We believe these NIH training programs are consistent with the spirit and the intent of the COSEPUP recommendations.

As Dr. Varmus indicated in his testimony, it is not clear that all graduate programs explain the diversity of career options available to individuals with doctoral degrees in biomedical and behavioral sciences. As a result, some graduate students erroneously believe that academic research positions are their only career choice. A stagnant academic market, therefore, has meant disappointment for many recent graduates. There are many other non-academic, and in some cases, non-research opportunities in which biomedical and behavioral scientists can use their training and expertise. Graduate institutions are in the best position to disseminate information about traditional and non-traditional careers for scientists. And, there is support for the idea that students should be exposed to this information early in their enrollment.

The NIH plans to use the leverage offered by training grants to encourage institutions to develop methods of exposing students to alternate career opportunities. In the past, we have

Provide better information and guidance:

- Graduate scientists and engineers and their advisors should receive more up-to-date and accurate information to help them make informed decisions about professional careers; broad electronic access to such information should be provided through a concerted nationwide effort.
- Academic departments should provide the information referred to above to prospective and current students in a timely manner and should also provide career advice to graduate students. Students should have access to information on the full range of employment possibilities.
- Students should be encouraged to consider three alternative pathways at the point when they have met their qualifying requirements.
- The National Science Foundation should continue to improve the coverage, timeliness, and clarity of analysis of data on the education and employment of scientists and engineers in order to support better national decision-making about human resources in science and technology.

asked graduate institutions to establish courses in the responsible conduct of science. In the process of setting up these courses, institutions have been very innovative in developing ways of teaching the importance of integrity in science. After a period of encouraging the development of these instructional skills, we began requiring that all institutions with training grants establish such a course. We plan to use a similar process with instruction in alternative careers. Over the next several months we will work with our extramural advisors to identify appropriate methods for dissemination of career information. It is expected that by the end of this fiscal year, there will be some agreement about the best way to teach this information and the best way to encourage widespread adoption of instruction in career options.

The NIH is also in the process of generating better information about potential career outcomes. We are evaluating our research training programs by examining the subsequent employment and research involvement of former trainees. This study will use data in existing databases and will develop information on non-academic employment outcomes using a survey. We also plan to establish a long-term career tracking system that will eventually provide up-to-date information about career opportunities. We have recently funded a new NAS study that will examine reasons for the reduction in the number of scientists under the age of 36 who apply for NIH research grants. This study will explore the need for increased training periods and will make recommendations about an appropriate NIH intervention. The career information that we gather from these studies and through our collaborations with the National Science Foundation will be disseminated at NIH workshops, on electronic information systems, and by targeted mailings to directors of NIH research training programs.

Devise a National Human-Resource Policy for Advanced Scientists and Engineers

- A national discussion group -- including representatives of governments, universities, industries, and professional organizations -- should deliberately examine the goals, policies, conditions, and unresolved issues of graduate-level human resources.

The NIH and the NAS work together to help resolve issues related to the supply and demand for life scientists and to determine what part of the Nation's overall training needs should be satisfied by NIH training grants and fellowships. These studies are conducted every four years as required by Section 489 of the Public Health Service Act. The last report, Meeting the Nation's Needs for Biomedical and Behavioral Scientists, was published in 1994. In that report, the NAS endorsed the use of training grants and recommended that the total number of graduate traineeships and fellowships should remain approximately constant until the end of the century.

Describe the proper balance between traineeships and fellowships

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Describe the proper balance between traineeships and fellowships

At the current time, in this country, the NIH supports about 15 percent of the approximately 70,000 full-time graduate students in biomedical sciences through research assistantships, about 8 percent through traineeships, and about 2 percent through fellowships. In behavioral sciences, the NIH contribution is much smaller. We doubt that there is any magical ratio that would be ideal in all disciplines or in all departments, but believe the use of traineeships during the period before qualifying examinations makes sense. Training grants encourage an institution to offer broader didactic and research experiences so the students can ultimately better adapt to changing national needs. As the student begins his or her dissertation research, support by a research assistantship becomes more defensible. Using this logic, it could be concluded that there should be approximate parity between traineeships and research assistantships, while offering a substantially smaller number graduate fellowships. Graduate fellowships would be reserved for the most outstanding students, who can benefit from the experience of applying for their own support, or for students in less research intensive universities, where a training grant is not an option.

One of the strengths of the NIH training grant model is that it encourages institutions to think very seriously about a comprehensive graduate training experience. Generally, institutions with training grant support develop a graduate training program that benefits not only the trainees, but all of the students in the program. Rather than considering the ratio of various support mechanisms, it may be more useful to consider the total number of training positions in terms of this broader influence on institutions and the students. The other issue, of course, is the need to keep traineeships attractive with respect to other sources of support so that institutions will select their more promising students for these positions. Issues related to the number of positions and the total income provided per position always generate tension as the NIH approaches a new budget year. The NAS quadrennial report on the need for biomedical and behavioral scientists provides invaluable assistance in these decisions.

AMERICAN CHEMICAL SOCIETY
1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
(202) 872-4477

KATHLEEN A. REAM
DIRECTOR
GOVERNMENT RELATIONS AND SCIENCE POLICY

August 9, 1995

The Honorable Steven H. Schiff
Chairman
Subcommittee on Basic Research
Committee on Science
U. S. House of Representatives
Washington, D.C. 20515-6301

Dear Chairman Schiff:

On behalf of the American Chemical Society, I would like to thank you for the opportunity given the ACS to testify before your Subcommittee on the NAS graduate education report. During the Society's testimony, Dr. Ned Heindel referenced a recent survey conducted for the ACS on the employment of PhDs who received their degrees in the chemical sciences during the years 1988 through 1994. As you requested, enclosed is a copy of that ***preliminary report***.

I also would like to reaffirm that the American Chemical Society stands ready to help the Subcommittee in any future deliberations on graduate education in the United States.

Sincerely yours,

Kathleen A. Ream

Enclosure

pc: Mr. C. Cadena
Dr. N. D. Heindel w/o Encl.

PRELIMINARY

SUBJECT TO FINAL REVIEW

REPORT ON

THE SURVEY OF DOCTORAL MENTORS CONCERNING CURRENT EMPLOYMENT OF PHD GRADUATES

Work conducted under contract with

the

AMERICAN CHEMICAL SOCIETY

by

David C. Montgomery
Independent Consultant
4512 Cortland Road
Chevy Chase, Maryland 20815

May 15, 1995

BACKGROUND

Concern over the future of PhD graduates has arisen from recent discussions of changing employment patterns, and awareness of anecdotal evidence of the difficulty of placing PhDs in permanent positions has increased. Several committees of the American Chemical Society (ACS) have expressed concern over the length of time graduates spend in post-doctoral positions. "Shaping the Future: The Chemical Research Environment in the Next Century," the 1994 ACS report from the Interactive Presidential Colloquium, reached the preliminary conclusion that "more Ph.D. granting university departments now exist than the number that can be adequately supported in the economic climate of the 1990s." (ACS, 1994a, p. 16). The colloquium recommended that ACS "should utilize its resources to collect benchmarking data that would provide information on a variety of topics including ... hiring distributions, and the number of Ph.D.s in the 'post-doc pipeline' during a given period. This information is critical to establishing which departments are producing the high quality, adaptable Ph.D.s required by industry, one of the most important customers of these institutions." (ACS, 1994a, p. 17).

In 1994, ACS committees (the Presidential Task Force on Doctoral Education and Committee on Economic and Professional Affairs) and staff designed a questionnaire to elicit from faculty who had supervised students in PhD programs (the "mentors") information on the current occupational status of recent PhD graduates. In January, 1995, ACS contracted with an independent consultant to administer the national survey of the mentors and to analyze the results. The survey was mailed to chemistry faculty of PhD granting departments in the U.S. with an original mailing in January followed by a second in February.

SURVEY RESULTS

OVERALL

The survey resulted in employment information on 8,956 PhDs who received their degrees in the U.S. during the years 1988 through 1994. Given the estimate of 14,436 PhD degrees granted in chemistry during that period, the survey results cover 62 percent of the total number of graduates possible.

Table 1 summarizes the current status of the graduates as derived from the survey. The columns represent the categories of employment that could be chosen by the mentors. (See Appendix A for technical notes on the survey and the resulting tables. For reference, the survey questionnaire and cover letters are in Appendix B.)

The occupational patterns are distinctly different for students who entered their graduate program as U.S. citizens and those entering with temporary visas. The latter are termed "temporary visas." (The mentors were asked to classify the graduates upon their entrance to graduate school rather than picking up any change in citizenship.) Tables 2 and 3 separate the graduates into these two classifications. As expected, the number of

temporary visas who returned to their country of origin is far greater than the number of U.S. citizens found currently in another country (our interpretation of the few times the category "returned to country of origin" was given for U.S. citizens). The large percentage in that single category (up to 42 percent in one year) for the temporary visas, of course, affects the percentages reported in the other categories. The graduates in each citizenship classification, however, show qualitatively the same dependence on time after graduation. While half the graduates were in postdocs one year after graduation, the percentage fell as the length of time after graduation increased. Just 8 percent and 14 percent of those graduating in 1988 (U.S. citizens and temporary visas, respectively) were postdocs in 1995. This major finding is graphed in Figure 1.

INSTITUTIONAL PRODUCTION LEVELS

One major question has been the extent to which the size of the institution granting the degree affects the graduate's employment. Do graduates of large departments fare better than those of small departments? The 185 institutions of the mentors were therefore arrayed according to the number of PhDs they had produced over the past seven years (CPT, 1994). To present the effects of size, we divided the institutions into five groups. In order to assure a reasonable number of responses from the universities in the group with the lowest number of graduates, we used "pentiles" of approximately 35 for the top four[1] and 47 institutions in the lowest group, "pentile 5." The groupings are shown in Table 4. The top pentile generated a total of 6,937 PhD graduates over the seven years, 48.1 percent of the grand total of 14,436. Tables 5, 6, 7, 8, and 9 present the basic results for each of the pentiles.

As seen above, results on U.S. citizens and temporary visas are different. In order to show the results from these classifications without excessive information, we looked for groups of institutions that are reasonably homogeneous with respect to citizenship mix. The following tabulation shows percentages by pentile:

Pentile	Number of U.S. Citizens in survey	Number of Temp. Visas in survey	Temp. Visas as % of total in survey
1	3249	869	21.1
2	1620	488	23.1
3	990	441	30.8
4	555	186	25.1
5	367	173	30.4

[1]To avoid splitting institutions with the same number of graduates between pentiles, we shifted two institutions at the top or bottom of a pentile. The resulting numbers of institutions in pentiles 1, 2, 3, and 4 are 34, 36, 36, and 34, respectively.

The percentages allow a combination into two groups. So we have combined pentiles 1 and 2 for one group -- the 70 institutions producing the highest number of PhDs -- and pentiles 3, 4, and 5 for a second group, the so-called lower production group. Tables 10, 11, 12, and 13 demonstrate the patterns for U.S. citizens separate from temporary visas for each of the two groups of institutions distinguished by production level. Compared to those from the lower production group, U.S. citizens graduating from the higher production group tend to begin with higher percentages in postdocs but have lower percentages of their graduates in postdocs following six years after graduation. For example, combining the first two years after graduation, the postdoc percentages are 47.0 and 40.5 percent (higher and lower production, respectively) while the combination of the sixth and seventh years yields 8.1 and 10.5 percent (higher and lower production, respectively). This distinction is not observed, however, for the temporary visas.

Two other displays of the information address the possibility of "non-linear effects." Tables 14 and 15 return to the separation into five pentiles. Each separates U.S. citizens from temporary visas for comparisons of one employment category. Table 14 presents unemployment rate with all years combined. For the U.S. citizens, there is no significant difference among the pentiles. For the temporary visas, there is a tendency for the institutions at intermediate production levels to graduate PhDs with lower unemployment rates, but the small numbers of unemployed graduates in all pentiles reduce confidence in any conclusion.[2] Similarly, Table 15 combines the early and the recent years to focus on postdoctoral percentages. The highest and lowest pentiles produce the lowest percentages of U.S.-citizen postdocs after six years, but again the small numbers frustrate firm conclusions.[3]

MENTOR RANK

The survey also allowed investigation of the possibility of distinction between the graduates of mentors who reported that they were currently ranked as Professors (possibly in combination with other titles such as department chair) in contrast to those with mentors in other ranks. The only other rank that was reported was Associate Professor. Many respondents left the item blank. Tables 16 and 17 show the comparison. Except for the fact that Associate Professors have not been faculty members as long as Professors, meaning that they produced fewer graduates in the early years, no differences between these groups is noteworthy.

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[2]Differences between the pentiles and the total for all temporary visas are statistically significant. Chi squared for U.S. citizens and temporary visas is, respectively, 2.3 and 9.7, with four degrees of freedom, implying significance at the .05 level for the latter, not for the U.S. citizens.

[3]The distribution of U.S.-citizen postdocs in 1988 and 1989, by pentile, is significantly different from their total in those years. Chi squared for U.S. citizens and temporary visas is, respectively, 9.6 and 2.7, implying statistical significance at the .05 level for the former.

MENTOR'S SUBFIELD

Previous discussions raised the possibility that the "subfield" of chemistry pursued by the graduates may affect their employment. The survey requested the mentor to indicate his or her own subfield. It must be emphasized that the graduate might not be in that subfield, and the possibility of switching may reduce observance of any real effects. Table 18 shows the unemployment rates derived from the survey, combining all graduation years, according to the mentor's subfield. The effect that could call for more study is the relatively high rate found for the graduates of mentors who left the subfield blank. The rates approximate 2 percent, and there are few subfields with enough graduates to determine whether differences among the unemployment rates are important. Excluding graduates of mentors with a blank subfield, the differences are not statistically significant.[4]

The absolute numbers are higher for a comparison across subfields of the percentage of graduates in postdocs, as shown in Table 19. The table contrasts percentages for the earliest and most recent years, separating U.S. citizens and temporary visas. Again, mentors not reporting their subfield produced anomalous results. Apart from them, relatively high postdoc percentages occur for the graduates out six or seven years whose mentors were in Theoretical and Physical Chemistry. However, none of the subfields is significantly different from the total.[5]

For a comparison of graduates' employment categories according to subfield, Table 20 combines all graduation years. The table shows clearly that Analytical Chemistry graduates tend to go into Industry, not into postdocs. The highest percentage in postdocs is associated with Biochemistry. Physical Chemistry graduates are most likely to take temporary jobs. Theoretical Chemists show the highest percentages in three important categories: Government, Four-year academic institutions, and jobs outside Chemistry.

OCCUPATIONS OUTSIDE CHEMISTRY

Survey respondents were asked to name the job if the graduate was employed outside Chemistry in the U.S. Table 21 tabulates those answers. The most frequent responses were related to computing, law, and medicine. It should be emphasized that the mentors' responses were the mentors' designations, not a choice between categories given by the questionnaire.

GEOGRAPHIC EFFECTS

Economic conditions differ across the country, and it appeared possible that sluggish conditions in certain regions might affect the survey results. Specifically, the 1994 unemployment rate averaged 6.1 percent nationally; but it ranged, by state, from 8.6

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[4]Chi squared is 8 or less.

[5]According to t-tests at the .05 level.

percent in California to 2.9 percent in Nebraska. By region, high unemployment occurred in the West (7.2 percent) and Pacific states (8.0 percent), while unemployment was low in the West North Central (4.2 percent) and East North Central (5.5 percent) states.[6]

To pursue the line of reasoning, we separated the survey responses according to the geographic region of the mentor's institution for two further tables. Table 22 shows unemployment rates for the PhDs for all graduation years by region. The only region that stands out is, perversely, the East North Central, with a high of 3.9 percent.[7] As above, the total workforce of that region had low unemployment. Table 23 then makes the comparison for postdoc percentages. Although there are differences across the institutions' regions, they do not follow the economic pattern measured otherwise.[8] We conclude that the graduates' employment status is not significantly tied to their institutions' regions.

GRADUATES IN INDUSTRY

The importance of the role of universities in preparing graduates for industrial positions warrants a review of the foregoing tables that focuses on industry. Tables 2 and 3 show that the percentage of graduates found in industry increases over time rather quickly, reaching a plateau of sorts after four years following graduation. The plateau differs for U.S. citizens and temporary visas: about half the U.S. citizens wind up in industry in contrast to 23 to 28 percent of the temporary visas. However, after combining the groups and counting all PhD graduates who remain in the U.S. five or more years after graduation (graduation years 1988 through 1990), more than half the graduates are in industry.

With reference to Tables 10 through 13, the "higher production" institutions are more likely to provide graduates for industry (56 percent and roughly 25 percent in the last years, for U.S. and temporary visas, respectively) than are the "lower production" institutions (52 percent and roughly 20 percent in the same years, respectively). According to Table 20, the mentor subfields with the highest likelihood of the graduates going into industry are Analytical (54.0 percent), General (45.5 percent), and Organic (43.4 percent).

OTHER RESEARCH

The annual survey of graduates in Chemistry conducted by ACS gives information on

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[6]The data on unemployment rates (Bureau of Labor Statistics, 1994) followed the same assignment of states to regions as did the "standard" assignment used in previous ACS publications. (See, for example, ACS, 1994b.)

[7]The difference is statistically significant at the .01 level by t-test.

[8]For the 1988-89 combination, only the West North Central postdoc percentage is significantly higher than the nation's at the .05 level by t-test.

both salaries and employment status. Students who received PhDs during the academic year 1993-94 reported on their situation as of July through November 1994. Employment of the 388 respondents was as follows (ACS, 1994b):

Full-time in Chemistry	37.9%
Full-time in Non-Chemistry	2.3
Postdoctoral/Fellowship	40.2
Seeking employment [unemployed]	17.0
Not seeking employment	2.6
Total	100.0%

It is possible that those unemployed in 1994 found positions by the time of the current survey. The Department of Career Services Bulletin (ACS, 1994c) commenting on the trends notes, "The percent of doctoral graduates taking postdoctoral appointments is a measure of the demand for PhDs. ... This year the percent of ... graduates taking postdoctoral appointments was 40%, down from 45% last year. Rather than indicating an increase in demand, however, this may indicate that new doctorates are having a hard time obtaining postdoctoral fellowships as well as in obtaining full-time employment."

In the process of preparing recommendations on graduate education for scientists and engineers, staff of the National Research Council analyzed earlier data from the Survey of Doctorate Recipients (SDR) (Committee on Science, Engineering, and Public Policy, et al., 1995). They found indications of employment difficulties and reported "The unemployment rate [of all U.S. PhDs] as of 1993 ... was still low at 1.6% but was increased from the roughly 1.0% of the 1980s and 1.4% in 1991." (Ibid., p. 4-2). Their categories of employment for PhDs in Chemistry in 1991 showed[9] percentages of respondents broken out for "new" (1-4 years after U.S. PhD) and "recent" (5-8 years after U.S. PhD) graduates which are copied in Table 24, below. "Not employed" includes both those seeking and not seeking employment.

Results from the current survey were recast into a form that can be contrasted with the SDR, by omitting all graduates not in the U.S. and defining "recent" to be those 5 to 7 years after graduation. These percentages are also presented in Table 24. (They total more than 100 because of multiple responses.)

[9]The pre-publication copy of Reshaping the Graduate Education of Scientists and Engineers contained errors that will be corrected in the final publication. This report uses data from correspondence with the study director (McGeary, 1994).

TABLE 24
PERCENTAGES OF GRADUATES BY EMPLOYMENT CATEGORY

	Post-doctoral	Academe	Business/ Industry	U.S. Gov't	Other Employ	Not Empl
SDR (1991)						
"New"	13.8	19.2	57.7	3.1	1.9	4.4
"Recent"	2.5	21.2	60.9	2.4	6.2	6.9
Current (1995)						
"New"	38.4	11.3	34.1	4.2	9.9	3.7
"Recent"	11.8	17.2	51.4	6.3	10.3	3.2

The procedures followed in the two surveys were quite different. If the figures are truly comparable, however, a massive shift toward the employment of postdocs has occurred in the past four years.

The graduate education report (Committee on Science, et al., 1995), a report on federal scientists (Campbell, et al. 1993), and studies of professional associations cited in the former reports agree that the employment patterns for scientists have changed recently. There is no conclusion, however, on what rates of unemployment, temporary employment, or employment in postdoctoral positions would be deemed excessive. Although numerous studies address the problem of defining "full" employment or "oversupply," the problem is not solved.

FUTURE RESEARCH

Two concerns call for additional attention. The first is that the current survey reveals what mentors reported based on what they believe to be the status of their graduates, not in what the graduates themselves actually experienced. Introducing the mentors as an intervening step in the information gathering could produce error from two major sources: (1) It is unlikely that the mentors surveyed the graduates specifically for the current study; a sampling of respondents indicated that they had not. That is, the replies reported here are based on the most recent information the mentors had, which could be out of date. We would expect, therefore, that the employment data are skewed toward older patterns. The high percentages of postdocs reported for the early graduation years could be due in part to the mentors not hearing of moves out of those appointments. (2) The graduates for whom mentors had current information would tend to be those in less desirable jobs; e.g., postdocs seeking permanent positions would be asking their mentors for references. This factor would cause bias in both response rate (since mentors would be less likely to return the questionnaire if they had no idea of what had happened to the graduate) and favoring of the undesirable categories when a mentor did respond. It would be wise then to survey, directly, a sample of the graduates and compare their statements of employment status with their mentors'. Absent a survey of the graduates,

surveys of mentors allow internal comparisons, and the current survey provides a baseline for further surveys of the mentors to ascertain changes in their perceptions over time.

The second concern is the current meaning of postdoctoral appointments. This survey was initiated under the assumption that it is undesirable for PhDs to be postdocs six years after graduation. However, "postdocs" were not defined in the survey instrument, and the freedom left to mentors implies a variety of interpretations of "postdoc." It is also reported (Committee on Science, et al., 1995) that some employers are expecting longer terms in postdoc positions for full qualification as researchers. Furthermore, according to comments on the survey, some research groups in universities are rather separate from traditional graduate education and employ postdocs instead of graduate students. It is possible, then, that a change in the organization of research has given new meaning to postdocs. An increase in the number of postdocs might have some benefits. These possibilities suggest the value of a study of postdoctoral positions as related to the graduates' education, means of support, and research roles. Representative questions would be: What are and should be the purposes of postdoctoral positions? Are there equivalents to academic postdocs in industry? What do research grants assume about the use of postdocs? Are there changes in the attitude of researchers and recent graduates about holding postdocs?

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APPENDIX A

MAILING

Timing desired for the first mailing of the survey necessitated using a non-personalized "Dear Colleague" letter with a general questionnaire and existing mailing labels. Names and addresses of faculty members were drawn from the 1993 Directory of Graduate Research. Letters totaling 4,509 were sent first class to the faculty members on January 20, 1995. The mailing list was then computerized. Responses from the first mailing were "flagged;" and 3,291 letters and questionnaires were mailed, also first class, to non-respondents on February 28 in the second round. The computerization allowed a personalized cover letter and questionnaire to be mailed in the second round.

RESPONSES

A total of 1,735 valid questionnaires was received for analysis. Twelve other forms were returned only after the respondent removed all identifying information. We set these aside. An additional 392 letters or forms were received from individuals saying that they had no students to report. Additional information provided by some respondents on other students or other years was omitted from further consideration. Since many faculty members did not reply because they, legitimately, had nothing to report, we believe that a traditional measure of response rate that uses simply the number of replies is not useful in gauging the completeness of the survey.

The meaningful figure for interpreting the coverage of the desired population is the number of PhD graduates reported relative to that number produced. The 1,735 responses covered 8,956 PhDs who graduated during the years 1988 through 1994. The relevant rates of coverage by production pentile (with derivation of the pentiles explained in the text) are as follows:

	PhDs Produced	Number Accounted for in Survey	Fraction
Pentile 1	6937	4118	0.594
Pentile 2	3652	2108	0.577
Pentile 3	1995	1431	0.717
Pentile 4	1173	741	0.632
Pentile 5	679	540	0.795

So there is reasonable representation from each pentile. As another measure of how representative the responses were, the survey mailing list included 185 institutions with active departments that had produced PhDs during the period of interest. The mailing addresses of the respondents showed at least one reply from all but one of these institutions.

DATA STRUCTURE

The questionnaire data were entered into two dBase files, one containing information on the respondent including rank and subfield (the "address file") and the other containing one record for each year in which a mentor provided valid data. The latter file, on the graduates, consisted of 5,015 records. The 218 records for which the mentor's institution had changed from that in the mailing address were tied back to a "moved to" record in the address file. Two additional files were created to link (1) institutions with their PhD production (hence their pentiles) and (2) states with their geographic region.

INTERPRETATION OF THE SURVEY FORM

Some ambiguities in the form lead to alternative interpretations of what was truly intended by how the mentors entered their data. Two ambiguities were (1) the form gave no option for the graduate to work in another country unless he or she was on a temporary visa at the time of entering graduate school and (2) some of the choices for current occupation could overlap, e.g., "Currently in Temporary ... Employment" in "Industry" or working in a government laboratory affiliated with a university, which could lead to designating the graduate in both "Govt" and "Other acad." The first ambiguity would lead to the sum of the choices being less than the total number of graduates as entered by the mentor (unless the mentor placed the graduate in another category). The second would lead to the sum of the choices being greater than the mentor's separate statement of total graduates.

In addition, since the form provided no response category for the mentor who did not know the graduate's current location, such a mentor would have to skip all choices given, creating the situation in which the sum of the choices would be less than the mentor's total number of graduates.

Two other misleading patterns emerged upon inspection of the individual completed forms. (1) Many mentors did not enter the total but merely entered one or more of the choices for current occupation (sometimes by checking an item rather than giving a number), and (2) some mentors were stymied by how to respond for a graduate who gained U.S. citizenship after admission (for some, possibly after graduation) and split numbers between two lines presumably for the same graduate. (The instruction on the form was to count the status at the time of entrance.) Whereas the second problem could be interpreted when there was only one graduate in a year, it was very hard to unravel if the form showed multiple graduates.

Accordingly, we used the following interpretation when the total number of graduates given by the mentor did not agree with the sum of the categories listed by the mentor:

1. If the graduate total was blank, it was assumed to be the sum of the choices given.
2. If the graduate total was less than the sum of the choices, we used the total and assumed overlapping choices.
3. If the graduate total was greater than the sum, we used the total and assumed the missing choices were not on the form, e.g., "Do not know" or a choice such as "U.S. citizen employed out of the U.S."

In the final column of the basic tables, "sum less total," the "sum" refers to the sum of the choices given, and the "total" is the number of graduates as entered by the mentor. This column measures the difference between the number of multiple responses given for an individual graduate and the absence of employment information given for individuals who, mentors indicated, were graduates. The uncertainty in distribution across the employment categories introduced by this aspect of the responses is about 1 percent of the total.

APPENDIX B

SURVEY COVER LETTERS AND QUESTIONNAIRE

American Chemical Society

OFFICE OF THE PRESIDENT

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

Ned D. Heindel
President-Elect, 1993
President, 1994
Immediate Past President, 1995

January 20, 1995

Dear Colleague:

We need your help in collecting a more accurate census of employment in chemistry.

The 1994 ACS Employment and Salary Survey reports the highest unemployment rate for chemists in more than 20 years. We have anecdotal information and general perceptions that the situation is even bleaker for recent PhD graduates. Some leaders of our profession believe that many recent PhD recipients, while officially employed, are in fact stuck in temporary posts which offer little opportunity for advancement. ACS is deeply concerned about the employment outlook and several governance groups, including a special Presidential Task Force on Doctoral Education, are exploring what the Society might do to help. An accurate assessment of the employment status of recent PhD graduates is sorely needed.

We would like to know on the enclosed survey sheet what each student who received a PhD under your supervision in the years listed is doing *now* (not upon graduation). As the PhD mentor, you are in the best position to provide the accurate information necessary for the important work ahead.

We are also interested in any comments or suggestions you have related to the employment situation or how the education process could better prepare chemical professionals for entry into our ever changing job market. If the PhD program in your department has some unique features that give the graduates an advantage in the job market, we would appreciate receiving information about that program with your response. Please fax your completed survey to (202) 872-4529 or return it in the enclosed postage paid envelope by February 19, 1995. Thank you for your important contribution to this essential study.

Sincerely yours,

Ned D. Heindel

enclosures

American Chemical Society

OFFICE OF THE PRESIDENT

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

Ned D. Heindel
President-Elect, 1993
President, 1994
Immediate Past President, 1995

February 27, 1995

[redacted]

Dear Dr. [redacted]:

A few weeks ago I asked for your help in performing a census of employment in chemistry. If you have returned the questionnaire and it has crossed this letter in the mails, I thank you. If you have not completed the survey form yet, I encourage you to fill it out and return it to us. A copy of the form is enclosed for your use.

We have heard some reports that employment patterns for our recent PhD graduates are particularly unfavorable. It is important to discover whether these anecdotal reports are true. Regardless of how well you believe your graduates are doing, and even if you were responsible for few graduates during this period, we need your contribution to the whole picture.

Please complete the enclosed form for students who received the PhD under your supervision in the calendar years listed. Your response should describe what the graduates are doing *now*, not immediately after graduation. Please return the form by March 17, using the enclosed postage paid envelope or by fax to (202) 872-4529.

Thank you for participating in this essential study. Please let me know if you would like a summary of the study results.

Sincerely yours,

Ned D. Heindel

Your Name _____ Your Rank _____
Your Institution _____ Your Subfield _____

Survey of Doctoral Mentors Concerning Current Employment of Ph.D. Graduates

Please record the number of your Ph.D. graduates from each year in the appropriate column.

Year of PhD	Institution granting PhD (if different from above)	TOTAL # of PhD Grads (by citizenship)[1]	Currently in Post-Docs (US or abroad)	Currently in Temporary or Contract Employ-ment	CURRENTLY EMPLOYED IN CHEMISTRY IN THE U.S.:					IN U.S., EMPLOYED outside of Chemistry (what field?)	IN U.S., NOT EMPLOYED		RETURNED TO COUNTRY OF ORIGIN[2]
							ACADEMIA		Other Employ ment		Seeking Employ-ment	Not Seeking Employment	
					Industry	Govt	4 yr Coll. or Univ.	Other acad.					
1994		US/Perm Res:											
		Temporary Visas:											
1993		US/Perm Res:											
		Temporary Visas:											
1992		US/Perm Res:											
		Temporary Visas:											
1991		US/Perm Res:											
		Temporary Visas:											
1990		US/Perm Res:											
		Temporary Visas:											
1989		US/Perm Res:											
		Temporary Visas:											
1988		US/Perm Res:											
		Temporary Visas:											

[1] US/Perm Res=U.S. Citizens or Permanent Residents. Indicate status at entrance to graduate school.

[2] NonU.S. citizens only.

Please return to: American Chemical Society, 1.55 16th St., N.W., Washington, D.C. 20036 202-872-4529 (fax)

FIGURE 1

and

TABLES 1 through 23

Figure 1

Status of PhD graduates entering programs as U.S. citizens and on temporary visas

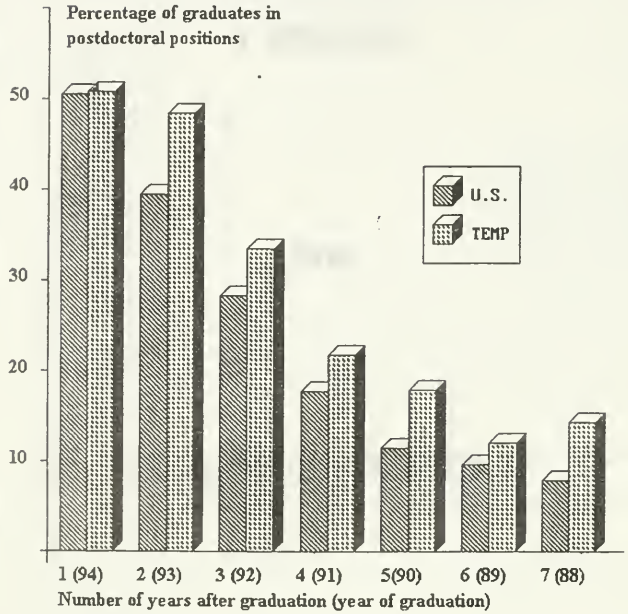

TABLE 1

CURRENT STATUS OF PHD GRADUATES - BY YEAR OF GRADUATION

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT SEEKING	EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	749	102	302	45	120	33	8	24	48	10	69	1480	30
1993	601	74	432	46	130	32	11	22	33	14	74	1438	31
1992	392	48	456	57	151	14	12	25	37	10	113	1312	3
1991	245	43	571	68	181	17	10	33	20	19	102	1299	10
1990	160	52	538	79	179	22	11	36	37	12	106	1231	1
1989	114	42	550	59	177	20	4	35	25	10	97	1132	1
1988	97	39	524	60	183	30	8	26	14	4	85	1064	6
ALL	2358	400	3373	414	1121	168	64	201	214	79	646	8956	82
As percentage of total for year													
1994	50.6%	6.9%	20.4%	3.0%	8.1%	2.2%	0.5%	1.6%	3.2%	0.7%	4.7%		
1993	41.8%	5.1%	30.0%	3.2%	9.0%	2.2%	0.8%	1.5%	2.3%	1.0%	5.1%		
1992	29.9%	3.7%	34.8%	4.3%	11.5%	1.1%	0.9%	1.9%	2.8%	0.8%	8.6%		
1991	18.9%	3.3%	44.0%	5.2%	13.9%	1.3%	0.8%	2.5%	1.5%	1.5%	7.9%		
1990	13.0%	4.2%	43.7%	6.4%	14.5%	1.8%	0.9%	2.9%	3.0%	1.0%	8.6%		
1989	10.1%	3.7%	48.6%	5.2%	15.6%	1.8%	0.4%	3.1%	2.2%	0.9%	8.6%		
1988	9.1%	3.7%	49.2%	5.6%	17.2%	2.8%	0.8%	2.4%	1.3%	0.4%	8.0%		
ALL	26.3%	4.5%	37.7%	4.6%	12.5%	1.9%	0.7%	2.2%	2.4%	0.9%	7.2%		

TABLE 2

CURRENT STATUS OF PHD GRADUATES - U.S. CITIZENS - BY YEAR OF GRADUATION

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	538	82	243	39	103	27	6	15	28	6	7	1065	29
1993	422	58	370	39	110	24	10	20	25	11	3	1068	24
1992	264	37	384	51	120	10	10	18	25	7	7	930	3
1991	177	34	484	63	155	11	10	29	15	13	7	988	10
1990	111	47	476	69	156	19	10	32	29	11	7	958	9
1989	88	34	500	59	153	17	4	32	16	9	7	917	2
1988	69	29	476	56	165	26	6	24	10	4	8	869	4
ALL	1669	321	2933	376	962	134	56	170	148	61	46	6795	81
As percentage of total for year													
1994	50.5%	7.7%	22.8%	3.7%	9.7%	2.5%	0.6%	1.4%	2.6%	0.6%	0.7%		
1993	39.5%	5.4%	34.6%	3.7%	10.3%	2.2%	0.9%	1.9%	2.3%	1.0%	0.3%		
1992	28.4%	4.0%	41.3%	5.5%	12.9%	1.1%	1.1%	1.9%	2.7%	0.8%	0.8%		
1991	17.9%	3.4%	49.0%	6.4%	15.7%	1.1%	1.0%	2.9%	1.5%	1.3%	0.7%		
1990	11.6%	4.9%	49.7%	7.2%	16.3%	2.0%	1.0%	3.3%	3.0%	1.1%	0.7%		
1989	9.6%	3.7%	54.5%	6.4%	16.7%	1.9%	0.4%	3.5%	1.7%	1.0%	0.8%		
1988	7.9%	3.3%	54.8%	6.4%	19.0%	3.0%	0.7%	2.8%	1.2%	0.5%	0.9%		
ALL	24.6%	4.7%	43.2%	5.5%	14.2%	2.0%	0.8%	2.5%	2.2%	0.9%	0.7%		

TABLE 3

CURRENT STATUS OF PHD GRADUATES - TEMPORARY VISAS - BY YEAR OF GRADUATION

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	211	20	59	6	17	6	2	9	20	4	62	415	1
1993	179	16	62	7	20	8	1	2	8	3	71	370	7
1992	128	11	72	6	31	4	2	7	12	3	106	382	0
1991	68	9	87	5	26	6	0	4	5	6	95	311	0
1990	49	5	62	10	23	3	1	4	8	1	99	273	-8
1989	26	8	50	0	24	3	0	3	9	1	90	215	-1
1988	28	10	48	4	18	4	2	2	4	0	77	195	2
ALL	689	79	440	38	159	34	8	31	66	18	600	2161	1
As percentage of total for year													
1994	50.8%	4.8%	14.2%	1.4%	4.1%	1.4%	0.5%	2.2%	4.8%	1.0%	14.9%		
1993	48.4%	4.3%	16.8%	1.9%	5.4%	2.2%	0.3%	0.5%	2.2%	0.8%	19.2%		
1992	33.5%	2.9%	18.8%	1.6%	8.1%	1.0%	0.5%	1.8%	3.1%	0.8%	27.7%		
1991	21.9%	2.9%	28.0%	1.6%	8.4%	1.9%	0.0%	1.3%	1.6%	1.9%	30.5%		
1990	17.9%	1.8%	22.7%	3.7%	8.4%	1.1%	0.4%	1.5%	2.9%	0.4%	36.3%		
1989	12.1%	3.7%	23.3%	0.0%	11.2%	1.4%	0.0%	1.4%	4.2%	0.5%	41.9%		
1988	14.4%	5.1%	24.6%	2.1%	9.2%	2.1%	1.0%	1.0%	2.1%	0.0%	39.5%		
ALL	31.9%	3.7%	20.4%	1.8%	7.4%	1.6%	0.4%	1.4%	3.1%	0.8%	27.8%		

TABLE 4

Institutions on Mailing List
Grouped by Pentile
According to PhD Production

	Institution	State
Pentile 1		
	Univ. of Calif./Berkeley	CA
	Purdue University	IN
	MIT	MA
	Univ. of Illinois/Urbana	IL
	Univ. of Wisconsin/Madison	WI
	Texas A & M Univ.	TX
	Ohio State Univ.	OH
	Univ. of Calif./Los Angeles	CA
	IA State Univ. of Sci and Tech	IA
	Univ. NC at Chapel Hill	NC
	University of Minnesota	MN
	Pennsylvania State Univ.	PA
	Stanford University	CA
	Univ. of Texas/Austin	TX
	Univ. of Florida	FL
	Calif. Inst. of Technology	CA
	Univ. of Calif./San Diego	CA
	Indiana University	IN
	Northwestern Univ.	IL
	Michigan State Univ.	MI
	Cornell University	NY
	Harvard Univ.	MA
	Univ. of Chicago	IL
	Univ. of South Carolina	SC
	University of Washington	WA
	Yale Univ.	CT
	Univ. of Colorado/Boulder	CO
	Univ. of Cincinnati	OH
	Univ. of Maryland	MD
	Univ. of Pittsburgh	PA
	University of Michigan	MI
	Univ. of Penn.	PA
	Columbia University	NY
	Princeton Univ.	NJ
Pentile 2		
	Wayne State Univ.	MI
	University of Arizona	AZ
	Univ. of Calif./Davis	CA
	State Univ. NY Buffalo	NY
	University of Rochester	NY
	CUNY	NY
	State Univ. NY Stony Brook	NY
	VA Poly Inst./State Univ.	VA
	Univ. of MA Amherst	MA

Rutgers Univ. New Brunswick	NJ
Univ. of Calif./Irvine	CA
Univ. of S. Calif.	CA
Colorado State Univ.	CO
University of Utah	UT
Emory Univ.	GA
Univ. of Calif./Santa Barbara	CA
Univ. of Illinois/Chicago	IL
University of Iowa	IA
Duke Univ.	NC
LA State Univ./Baton Rouge	LA
Brown Univ.	RI
Univ. of Delaware	DE
Case Western Reserve Univ.	OH
Univ. of MA Lowell	MA
University of Nebraska	NE
Rice University	TX
University of Tennessee	TN
GA Inst. of Technology	GA
University of Houston	TX
Arizona State Univ.	AZ
Univ. of Virginia	VA
Rensselaer Poly Inst.	NY
University of Notre Dame	IN
Johns Hopkins Univ.	MD
University of Oregon	OR
Oregon State Univ.	OR

Pentile 3

New York University	NY
Univ. of CT	CT
Polytechnic Univ.	NY
University of Akron	OH
Lehigh Univ.	PA
University of Georgia	GA
Washington University	MO
Univ. of Calif./Riverside	CA
Syracuse University	NY
University of Oklahoma	OK
Northeastern Univ.	MA
Florida State Univ.	FL
Kansas State Univ.	KS
Texas Tech Univ.	TX
Oklahoma State Univ.	OK
NC State Univ.	NC
Brandeis Univ.	MA
University of New Mexico	NM
Georgetown Univ.	DC
University of Arkansas	AR
Boston Univ.	MA
Brigham Young Univ.	UT
Carnegie Mellon Univ.	PA
Vanderbilt University	TN
Clarkson Univ.	NY

Univ. of Alabama	AL
Clemson Univ.	SC
Univ. of Vermont	VT
Univ. of Missouri/Columbia	MO
Univ. of Calif./Santa Cruz	CA
North Dakota State Univ.	ND
State Univ. NY Binghamton	NY
Univ. of Wisconsin/Milwaukee	WI
University of Kentucky	KY
Miami University	OH
Univ. of Missouri/Rolla	MO

Pentile 4

Northern Illinois Univ.	IL
Univ. of North Texas	TX
University of Hawaii	HI
State Univ. NY Albany	NY
University of Kansas	KS
New Mexico State Univ.	NM
Colorado School of Mines	CO
Virginia Commonwealth Univ.	VA
S. Illinois Univ./Carbondale	IL
Wesleyan Univ.	CT
University of Texas/Arlington	TX
Rutgers Univ.	NJ
Tufts Univ.	MA
American University	DC
University of New Orleans	LA
Auburn University	AL
Dartmouth College	NH
Boston College	MA
Univ. of Louisville	KY
University of Miami	FL
Marquette University	WI
Univ. of NH	NH
Temple Univ.	PA
Seton Hall Univ.	NJ
Washington State Univ.	WA
University of Wyoming	WY
Univ. of Missouri/St. Louis	MO
Univ. of RI	RI
Ohio University	OH
Loyola Univ. of Chicago	IL
OR Grad. Inst. of Sci/Tech	OR
University of Idaho	ID
Howard University	DC
Univ. of South Florida	FL

Pentile 5

Drexel Univ.	PA
Univ. of Maine	ME
Clark Univ.	MA
Rockefeller Univ.	NY
Cleveland State Univ.	OH

Kent State Univ.	OH
Tulane University	LA
Texas Christian Univ.	TX
West Virginia Univ.	WV
Univ. of S. Mississippi	MS
Univ. of Alabama/Birmingham	AL
Univ. of MD/Baltimore County	MD
Univ. of North Dakota	ND
University of Toledo	OH
University of Nevada/Reno	NV
Mississippi State Univ.	MS
Stevens Inst. of Tech.	NJ
University of Mississippi	MS
Catholic Univ. of America	DC
Baylor University	TX
Inst. of Paper Sci. and Tech.	GA
San Diego State Univ.	CA
Univ. of Texas/Dallas	TX
Univ. of Detroit Mercy	MI
Univ. of Missouri/Kansas City	MO
Montana State Univ.	MT
University of Montana	MT
University of Memphis	TN
University of Denver	CO
Wichita State Univ.	KS
George Washington Univ.	DC
Bryn Mawr College	PA
MI Technological Univ.	MI
State Univ. NY - Envir. Sci.	NY
Wake Forest Univ.	NC
NM Inst. of Mining and Tech	NM
Worcester Poly Inst.	MA
Illinois Inst. of Tech.	IL
University of the Pacific	CA
Clark Atlanta Univ.	GA
Phila. Coll. Pharm. & Chem.	PA
Duquesne Univ.	PA
South Dakota State Univ.	SD
Indiana U/Purdue at Indianap.	IN
Univ. of Alaska/Fairbanks	AK
Scripps Research Inst.	CA
FL Inst. of Technology	FL

Note: Computer error in retrieving data from the Directory of Graduate Research resulted in the omission of Utah State University and Portland State University from the mailing list. They would appear in pentiles 4 and 5, respectively. They will be included in future surveys.

TABLE 5

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILE 1

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	355	44	147	16	54	13	1	16	17	5	31	691	8
1993	281	26	189	14	54	7	8	10	20	4	23	633	3
1992	174	23	214	22	60	6	4	12	23	4	48	598	-8
1991	90	12	293	27	97	8	5	14	9	5	42	604	-2
1990	61	17	249	36	98	10	2	18	19	2	40	558	-6
1989	42	18	252	23	95	10	2	10	21	5	34	515	-3
1988	41	16	250	25	114	20	3	10	6	2	36	519	4
ALL	1044	156	1594	163	572	74	25	90	115	27	254	4118	-4
As percentage of total for year													
1994	51.4%	6.4%	21.3%	2.3%	7.8%	1.9%	0.1%	2.3%	2.5%	0.7%	4.5%		
1993	44.4%	4.1%	29.9%	2.2%	8.5%	1.1%	1.3%	1.6%	3.2%	0.6%	3.6%		
1992	29.1%	3.8%	35.8%	3.7%	10.0%	1.0%	0.7%	2.0%	3.8%	0.7%	8.0%		
1991	14.9%	2.0%	48.5%	4.5%	16.1%	1.3%	0.8%	2.3%	1.5%	0.8%	7.0%		
1990	10.9%	3.0%	44.6%	6.5%	17.6%	1.8%	0.4%	3.2%	3.4%	0.4%	7.2%		
1989	8.2%	3.5%	48.9%	4.5%	18.4%	1.9%	0.4%	1.9%	4.1%	1.0%	6.6%		
1988	7.9%	3.1%	48.2%	4.8%	22.0%	3.9%	0.6%	1.9%	1.2%	0.4%	6.9%		
ALL	25.4%	3.8%	38.7%	4.0%	13.9%	1.8%	0.6%	2.2%	2.8%	0.7%	6.2%		

TABLE 6

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILE 2

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	179	21	58	13	31	7	5	5	17	4	15	345	10
1993	137	21	99	8	30	8	2	7	8	6	23	337	12
1992	83	14	98	18	41	3	1	6	3	1	20	284	4
1991	63	15	127	10	35	7	2	9	5	7	24	303	1
1990	40	10	140	16	43	7	4	9	7	6	22	297	7
1989	33	7	147	15	36	3	1	6	1	4	24	275	2
1988	26	14	143	16	27	3	1	9	6	0	20	267	-2
ALL	561	102	812	96	243	38	16	51	47	28	148	2108	34
As percentage of total for year													
1994	51.9%	6.1%	16.8%	3.8%	9.0%	2.0%	1.4%	1.4%	4.9%	1.2%	4.3%		
1993	40.7%	6.2%	29.4%	2.4%	8.9%	2.4%	0.6%	2.1%	2.4%	1.8%	6.8%		
1992	29.2%	4.9%	34.5%	6.3%	14.4%	1.1%	0.4%	2.1%	1.1%	0.4%	7.0%		
1991	20.8%	5.0%	41.9%	3.3%	11.6%	2.3%	0.7%	3.0%	1.7%	2.3%	7.9%		
1990	13.5%	3.4%	47.1%	5.4%	14.5%	2.4%	1.3%	3.0%	2.4%	2.0%	7.4%		
1989	12.0%	2.5%	53.5%	5.5%	13.1%	1.1%	0.4%	2.2%	0.4%	1.5%	8.7%		
1988	9.7%	5.2%	53.6%	6.0%	10.1%	1.1%	0.4%	3.4%	2.2%	0.0%	7.5%		
ALL	26.6%	4.8%	38.5%	4.6%	11.5%	1.8%	0.8%	2.4%	2.2%	1.3%	7.0%		

TABLE 7

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILE 3

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	119	19	49	11	25	4	2	1	5	1	13	240	9
1993	109	17	79	9	21	12	1	2	3	2	18	260	13
1992	55	7	82	7	25	3	5	5	4	3	25	220	1
1991	42	7	86	18	25	2	1	2	1	5	20	204	5
1990	29	12	83	14	22	3	3	4	6	1	22	201	-2
1989	17	11	73	12	15	3	1	6	2	0	26	166	0
1988	19	4	67	8	16	3	3	3	1	2	15	140	1
ALL	390	77	519	79	149	30	16	23	22	14	139	1431	27
As percentage of total for year													
1994	49.6%	7.9%	20.4%	4.6%	10.4%	1.7%	0.8%	0.4%	2.1%	0.4%	5.4%		
1993	41.9%	6.5%	30.4%	3.5%	8.1%	4.6%	0.4%	0.8%	1.2%	0.8%	6.9%		
1992	25.0%	3.2%	37.3%	3.2%	11.4%	1.4%	2.3%	2.3%	1.8%	1.4%	11.4%		
1991	20.6%	3.4%	42.2%	8.8%	12.3%	1.0%	0.5%	1.0%	0.5%	2.5%	9.8%		
1990	14.4%	6.0%	41.3%	7.0%	10.9%	1.5%	1.5%	2.0%	3.0%	0.5%	10.9%		
1989	10.2%	6.6%	44.0%	7.2%	9.0%	1.8%	0.6%	3.6%	1.2%	0.0%	15.7%		
1988	13.6%	2.9%	47.9%	5.7%	11.4%	2.1%	2.1%	2.1%	0.7%	1.4%	10.7%		
ALL	27.3%	5.4%	36.3%	5.5%	10.4%	2.1%	1.1%	1.6%	1.5%	1.0%	9.7%		

TABLE 8

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILE 4

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	53	9	25	2	3	4	0	1	8	0	4	106	3
1993	42	6	38	11	17	2	0	1	1	1	6	122	3
1992	42	1	38	7	10	0	1	1	3	2	8	109	4
1991	30	6	34	11	13	0	2	5	3	0	9	109	4
1990	21	4	44	10	8	2	2	2	3	3	11	108	2
1989	17	4	50	5	18	1	0	7	0	0	7	111	-2
1988	7	2	32	5	17	3	0	1	0	0	9	76	0
ALL	212	32	261	51	86	12	5	18	18	6	54	741	14
As percentage of total for year													
1994	50.0%	8.5%	23.6%	1.9%	2.8%	3.8%	0.0%	0.9%	7.5%	0.0%	3.8%		
1993	34.4%	4.9%	31.1%	9.0%	13.9%	1.6%	0.0%	0.8%	0.8%	0.8%	4.9%		
1992	38.5%	0.9%	34.9%	6.4%	9.2%	0.0%	0.9%	0.9%	2.8%	1.8%	7.3%		
1991	27.5%	5.5%	31.2%	10.1%	11.9%	0.0%	1.8%	4.6%	2.8%	0.0%	8.3%		
1990	19.4%	3.7%	40.7%	9.3%	7.4%	1.9%	1.9%	1.9%	2.8%	2.8%	10.2%		
1989	15.3%	3.6%	45.0%	4.5%	16.2%	0.9%	0.0%	6.3%	0.0%	0.0%	6.3%		
1988	9.2%	2.6%	42.1%	6.6%	22.4%	3.9%	0.0%	1.3%	0.0%	0.0%	11.8%		
ALL	28.6%	4.3%	35.2%	6.9%	11.6%	1.6%	0.7%	2.4%	2.4%	0.8%	7.3%		

TABLE 9

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILE 5

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	42	8	22	3	7	5	0	1	1	0	6	95	0
1993	31	4	26	4	8	3	0	2	1	1	4	84	0
1992	38	3	24	3	14	2	1	1	4	0	11	99	2
1991	20	3	31	2	10	0	0	3	2	2	7	78	2
1990	8	9	22	3	8	0	0	3	2	0	10	65	0
1989	4	2	25	4	13	3	0	6	1	1	6	61	4
1988	4	3	31	5	9	1	1	3	1	0	3	58	3
ALL	147	32	181	24	69	14	2	19	12	4	47	540	11
As percentage of total for year													
1994	44.2%	8.4%	23.2%	3.2%	7.4%	5.3%	0.0%	1.1%	1.1%	0.0%	6.3%		
1993	36.9%	4.8%	31.0%	4.8%	9.5%	3.6%	0.0%	2.4%	1.2%	1.2%	4.8%		
1992	38.4%	3.0%	24.2%	3.0%	14.1%	2.0%	1.0%	1.0%	4.0%	0.0%	11.1%		
1991	25.6%	3.8%	39.7%	2.6%	12.8%	0.0%	0.0%	3.8%	2.6%	2.6%	9.0%		
1990	12.3%	13.8%	33.8%	4.6%	12.3%	0.0%	0.0%	4.6%	3.1%	0.0%	15.4%		
1989	6.6%	3.3%	41.0%	6.6%	21.3%	4.9%	0.0%	9.8%	1.6%	1.6%	9.8%		
1988	6.9%	5.2%	53.4%	8.6%	15.5%	1.7%	1.7%	5.2%	1.7%	0.0%	5.2%		
ALL	27.2%	5.9%	33.5%	4.4%	12.8%	2.6%	0.4%	3.5%	2.2%	0.7%	8.7%		

TABLE 10

CURRENT STATUS OF PHD GRADUATES - U.S. CITIZENS - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILES 1 & 2
(HIGHER PRODUCTION)

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	397	50	166	26	74	16	4	13	20	5	5	760	16
1993	313	41	255	19	72	13	9	15	21	8	1	752	15
1992	192	28	268	36	83	8	5	13	17	4	7	661	0
1991	111	23	365	32	117	10	7	21	11	9	4	707	3
1990	77	23	348	43	126	14	6	23	19	8	4	687	4
1989	60	21	364	38	118	12	3	15	15	8	2	656	0
1988	46	22	359	38	126	20	3	17	9	2	4	646	0
ALL	1196	208	2125	232	716	93	37	117	112	44	27	4869	38
As percentage of total for year													
1994	52.2%	6.6%	21.8%	3.4%	9.7%	2.1%	0.5%	1.7%	2.6%	0.7%	0.7%		
1993	41.6%	5.5%	33.9%	2.5%	9.6%	1.7%	1.2%	2.0%	2.8%	1.1%	0.1%		
1992	29.0%	4.2%	40.5%	5.4%	12.6%	1.2%	0.8%	2.0%	2.6%	0.6%	1.1%		
1991	15.7%	3.3%	51.6%	4.5%	16.5%	1.4%	1.0%	3.0%	1.6%	1.3%	0.6%		
1990	11.2%	3.3%	50.7%	6.3%	18.3%	2.0%	0.9%	3.3%	2.8%	1.2%	0.6%		
1989	9.1%	3.2%	55.5%	5.8%	18.0%	1.8%	0.5%	2.3%	2.3%	1.2%	0.3%		
1988	7.1%	3.4%	55.6%	5.9%	19.5%	3.1%	0.5%	2.6%	1.4%	0.3%	0.6%		
ALL	24.6%	4.3%	43.6%	4.8%	14.7%	1.9%	0.8%	2.4%	2.3%	0.9%	0.6%		

TABLE 11

CURRENT STATUS OF PHD GRADUATES - TEMPORARY VISAS - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILES 1 & 2
(HIGHER PRODUCTION)

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	137	15	39	3	11	4	2	8	14	4	41	276	2
1993	105	6	33	3	12	2	1	2	7	2	45	218	0
1992	65	9	44	4	18	1	0	5	9	1	61	221	-4
1991	42	4	55	5	15	5	0	2	3	3	62	200	-4
1990	24	4	41	9	15	3	0	4	7	0	58	168	-3
1989	15	4	35	0	13	1	0	1	7	1	56	134	-1
1988	21	8	34	3	15	3	1	2	3	0	52	140	2
ALL	409	50	281	27	99	19	4	24	50	11	375	1357	-8
As percentage of total for year													
1994	49.6%	5.4%	14.1%	1.1%	4.0%	1.4%	0.7%	2.9%	5.1%	1.4%	14.9%		
1993	48.2%	2.8%	15.1%	1.4%	5.5%	0.9%	0.5%	0.9%	3.2%	0.9%	20.6%		
1992	29.4%	4.1%	19.9%	1.8%	8.1%	0.5%	0.0%	2.3%	4.1%	0.5%	27.6%		
1991	21.0%	2.0%	27.5%	2.5%	7.5%	2.5%	0.0%	1.0%	1.5%	1.5%	31.0%		
1990	14.3%	2.4%	24.4%	5.4%	8.9%	1.8%	0.0%	2.4%	4.2%	0.0%	34.5%		
1989	11.2%	3.0%	26.1%	0.0%	9.7%	0.7%	0.0%	0.7%	5.2%	0.7%	41.8%		
1988	15.0%	5.7%	24.3%	2.1%	10.7%	2.1%	0.7%	1.4%	2.1%	0.0%	37.1%		
ALL	30.1%	3.7%	20.7%	2.0%	7.3%	1.4%	0.3%	1.8%	3.7%	0.8%	27.6%		

TABLE 12

CURRENT STATUS OF PHD GRADUATES - U.S. CITIZENS - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILES 3, 4, & 5
(LOWER PRODUCTION)

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	141	31	76	13	29	11	2	2	8	1	2	303	13
1993	109	17	114	20	38	11	1	5	4	3	2	315	9
1992	72	9	116	15	36	2	5	5	8	3	0	268	3
1991	66	11	119	31	37	1	3	8	4	4	3	280	7
1990	33	24	128	26	30	5	4	9	10	3	3	270	5
1989	27	13	133	21	35	5	1	17	1	1	5	257	2
1988	23	7	116	17	39	6	3	7	1	2	2	219	4
ALL	471	112	802	143	244	41	19	53	36	17	17	1912	43
As percentage of total for year													
1994	46.5%	10.2%	25.1%	4.3%	9.6%	3.6%	0.7%	0.7%	2.6%	0.3%	0.7%		
1993	34.6%	5.4%	36.2%	6.3%	12.1%	3.5%	0.3%	1.6%	1.3%	1.0%	0.6%		
1992	26.9%	3.4%	43.3%	5.6%	13.4%	0.7%	1.9%	1.9%	3.0%	1.1%	0.0%		
1991	23.6%	3.9%	42.5%	11.1%	13.2%	0.4%	1.1%	2.9%	1.4%	1.4%	1.1%		
1990	12.2%	8.9%	47.4%	9.6%	11.1%	1.9%	1.5%	3.3%	3.7%	1.1%	1.1%		
1989	10.5%	5.1%	51.8%	8.2%	13.6%	1.9%	0.4%	6.6%	0.4%	0.4%	1.9%		
1988	10.5%	3.2%	53.0%	7.8%	17.8%	2.7%	1.4%	3.2%	0.5%	0.9%	0.9%		
ALL	24.6%	5.9%	41.9%	7.5%	12.8%	2.1%	1.0%	2.8%	1.9%	0.9%	0.9%		

TABLE 13

CURRENT STATUS OF PHD GRADUATES - TEMPORARY VISAS - BY YEAR OF GRADUATION
INSTITUTIONS BY NUMBER OF GRADUATES - PENTILES 3, 4, & 5
(LOWER PRODUCTION)

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	73	5	20	3	6	2	0	1	6	0	21	138	-1
1993	73	10	29	4	8	6	0	0	1	1	26	151	7
1992	63	2	28	2	13	3	2	2	3	2	44	160	4
1991	26	5	32	0	11	1	0	2	2	3	33	111	4
1990	25	1	21	1	8	0	1	0	1	1	40	104	-5
1989	11	4	15	0	11	2	0	2	2	0	34	81	0
1988	7	2	14	1	3	1	1	0	1	0	25	55	0
ALL	278	29	159	11	60	15	4	7	16	7	223	800	9
As percentage of total for year													
1994	52.9%	3.6%	14.5%	2.2%	4.3%	1.4%	0.0%	0.7%	4.3%	0.0%	15.2%		
1993	48.3%	6.6%	19.2%	2.6%	5.3%	4.0%	0.0%	0.0%	0.7%	0.7%	17.2%		
1992	39.4%	1.3%	17.5%	1.3%	8.1%	1.9%	1.3%	1.3%	1.9%	1.3%	27.5%		
1991	23.4%	4.5%	28.8%	0.0%	9.9%	0.9%	0.0%	1.8%	1.8%	2.7%	29.7%		
1990	24.0%	1.0%	20.2%	1.0%	7.7%	0.0%	1.0%	0.0%	1.0%	1.0%	38.5%		
1989	13.6%	4.9%	18.5%	0.0%	13.6%	2.5%	0.0%	2.5%	2.5%	0.0%	42.0%		
1988	12.7%	3.6%	25.5%	1.8%	5.5%	1.8%	1.8%	0.0%	1.8%	0.0%	45.5%		
ALL	34.8%	3.6%	19.9%	1.4%	7.5%	1.9%	0.5%	0.9%	2.0%	0.9%	27.9%		

TABLE 14

UNEMPLOYMENT RATE FOR U.S. CITIZENS AND TEMPORARY VISAS
BY INSTITUTIONAL PRODUCTION LEVEL (PENTILES)
ALL YEARS OF GRADUATION

PENTILE	U.S. CITIZENS			TEMPORARY VISAS		
	Number Seeking But Not Employed	Total from Institutions in Pentile	Percent Unemployed	Number Seeking But Not Employed	Total from Institutions in Pentile	Percent Unemployed
1	80	3249	2.5	35	869	4.0
2	32	1620	2.0	15	488	3.1
3	18	990	1.8	4	441	0.9
4	11	555	2.0	7	186	3.8
5	7	367	1.9	5	173	2.9
ALL	148	6781	2.2	66	2157	3.1

TABLE 15

U.S. CITIZENS & TEMPORARY VISAS IN POSTDOCTORAL POSITIONS
BY INSTITUTIONAL PRODUCTION LEVEL (PENTILES)
COMPARING TWO MOST RECENT GRADUATION YEARS (1993 & 1994)
WITH TWO EARLIEST GRADUATION YEARS (1988 & 1989)

	U.S. CITIZENS			TEMP VISAS		
	Number of Postdocs	Total from Pentile	Postdoc Percent	Number of Postdocs	Total from Pentile	Postdoc Percent
	PENTILE 1					
1993 & 1994	494	1028	48.1	142	296	48.0
1988 & 1989	57	853	6.7	26	181	14.4
	PENTILE 2					
1993 & 1994	216	484	44.6	100	198	50.5
1988 & 1989	49	449	10.9	10	93	10.8
	PENTILE 3					
1993 & 1994	140	328	42.7	88	172	51.2
1988 & 1989	26	232	11.2	10	74	13.5
	PENTILE 4					
1993 & 1994	64	169	37.9	31	59	52.5
1988 & 1989	17	148	11.5	7	39	17.9
	PENTILE 5					
1993 & 1994	46	121	38.0	27	58	46.6
1988 & 1989	7	96	7.3	1	23	4.3
	TOTAL					
1993 & 1994	960	2130	45.1	388	783	49.6
1988 & 1989	156	1778	8.8	54	410	13.2

TABLE 16

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
BY RANK OF MENTOR REPORTED AS PROFESSOR

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	565	75	228	36	79	24	4	16	34	8	50	1099	20
1993	436	56	322	35	100	20	8	18	23	7	52	1056	21
1992	319	37	364	49	116	13	11	18	23	7	87	1043	1
1991	214	34	457	51	154	11	9	27	12	14	85	1061	7
1990	124	47	444	70	156	20	6	27	21	11	94	1018	2
1989	92	33	460	51	155	14	3	26	9	9	86	940	-2
1988	80	34	449	50	159	30	6	23	13	3	76	923	0
ALL	1830	316	2724	342	919	132	47	155	135	59	530	7140	49
As percentage of total for year													
1994	51.4%	6.8%	20.7%	3.3%	7.2%	2.2%	0.4%	1.5%	3.1%	0.7%	4.5%		
1993	41.3%	5.3%	30.5%	3.3%	9.5%	1.9%	0.8%	1.7%	2.2%	0.7%	4.9%		
1992	30.6%	3.5%	34.9%	4.7%	11.1%	1.2%	1.1%	1.7%	2.2%	0.7%	8.3%		
1991	20.2%	3.2%	43.1%	4.8%	14.5%	1.0%	0.8%	2.5%	1.1%	1.3%	8.0%		
1990	12.2%	4.6%	43.6%	6.9%	15.3%	2.0%	0.6%	2.7%	2.1%	1.1%	9.2%		
1989	9.8%	3.5%	48.9%	5.4%	16.5%	1.5%	0.3%	2.8%	1.0%	1.0%	9.1%		
1988	8.7%	3.7%	48.6%	5.4%	17.2%	3.3%	0.7%	2.5%	1.4%	0.3%	8.2%		
ALL	25.6%	4.4%	38.2%	4.8%	12.9%	1.8%	0.7%	2.2%	1.9%	0.8%	7.4%		

TABLE 17

CURRENT STATUS OF PHD GRADUATES - ALL CITIZENSHIP - BY YEAR OF GRADUATION
BY RANK OF MENTOR REPORTED AS ASSOCIATE PROFESSOR

YEAR	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS	SUM LESS TOTAL
As number													
1994	112	16	44	5	20	7	2	6	4	0	13	221	8
1993	102	13	55	8	22	8	1	3	3	4	15	225	9
1992	45	9	45	7	25	1	0	5	2	3	16	156	2
1991	19	4	61	10	11	5	0	3	3	3	8	125	2
1990	15	4	48	3	10	1	2	5	7	1	5	98	3
1989	8	5	38	2	10	4	0	7	0	1	2	76	1
1988	4	2	25	3	5	0	0	1	0	1	6	46	1
ALL	305	53	316	38	103	26	5	30	19	13	65	947	26
As percentage of total for year													
1994	50.7%	7.2%	19.9%	2.3%	9.0%	3.2%	0.9%	2.7%	1.8%	0.0%	5.9%		
1993	45.3%	5.8%	24.4%	3.6%	9.8%	3.6%	0.4%	1.3%	1.3%	1.8%	6.7%		
1992	28.8%	5.8%	28.8%	4.5%	16.0%	0.6%	0.0%	3.2%	1.3%	1.9%	10.3%		
1991	15.2%	3.2%	48.8%	8.0%	8.8%	4.0%	0.0%	2.4%	2.4%	2.4%	6.4%		
1990	15.3%	4.1%	49.0%	3.1%	10.2%	1.0%	2.0%	5.1%	7.1%	1.0%	5.1%		
1989	10.5%	6.6%	50.0%	2.6%	13.2%	5.3%	0.0%	9.2%	0.0%	1.3%	2.6%		
1988	8.7%	4.3%	54.3%	6.5%	10.9%	0.0%	0.0%	2.2%	0.0%	2.2%	13.0%		
ALL	32.2%	5.6%	33.4%	4.0%	10.9%	2.7%	0.5%	3.2%	2.0%	1.4%	6.9%		

TABLE 18

UNEMPLOYMENT RATE FOR U.S. CITIZENS AND TEMPORARY VISAS
BY MENTOR'S SUBFIELD
ALL YEARS OF GRADUATION

U.S. CITIZENS			TEMPORARY VISAS		
Number Seeking But Not Employed	Total from Mentor's Subfield	Percent Unemployed	Number Seeking But Not Employed	Total from Mentor's Subfield	Percent Unemployed
BLANK (Unknown)					
30	699	4.3	28	260	10.8
ORGANIC					
31	1652	1.9	10	520	1.9
INORGANIC					
17	854	2.0	5	274	1.8
ANALYTIC					
14	856	1.6	5	204	2.5
PHYSICAL					
22	1001	2.2	9	366	2.5
BIOCHEM					
4	385	1.0	2	126	1.6
THEORETIC					
3	116	2.6	1	26	3.8
GENERAL					
2	132	1.5	0	35	0.0
OTHER (INCLUDING JOINT)					
25	1100	2.3	6	350	1.7
TOTAL					
148	6795	2.2	66	2161	3.1

TABLE 19

U.S. CITIZENS & TEMPORARY VISAS IN POSTDOCTORAL POSITIONS
BY MENTOR'S SUBFIELD
COMPARING TWO MOST RECENT GRADUATION YEARS (1993 & 1994)
WITH TWO EARLIEST GRADUATION YEARS (1988 & 1989)

	U.S. CITIZENS			TEMP VISAS		
	Number of Postdocs	Total from Subfield	Postdoc Percent	Number of Postdocs	Total from Subfield	Postdoc Percent
BLANK (Unknown)						
1993 & 1994	87	202	43.1	36	80	45.0
1988 & 1989	31	214	14.5	12	44	27.3
ORGANIC						
1993 & 1994	265	510	52.0	96	187	51.3
1988 & 1989	40	418	9.6	9	96	9.4
INORGANIC						
1993 & 1994	131	265	49.4	59	102	57.8
1988 & 1989	11	235	4.7	7	50	14.0
ANALYTIC						
1993 & 1994	75	282	26.6	31	79	39.2
1988 & 1989	12	220	5.5	4	48	8.3
PHYSICAL						
1993 & 1994	144	319	45.1	67	140	47.9
1988 & 1989	26	241	10.8	11	65	16.9
BIOCHEM						
1993 & 1994	78	122	63.9	30	46	65.2
1988 & 1989	9	102	8.8	3	22	13.6
THEORETIC						
1993 & 1994	20	36	55.6	5	8	62.5
1988 & 1989	4	24	16.7	0	5	0.0
GENERAL						
1993 & 1994	19	47	40.4	2	10	20.0
1988 & 1989	3	39	7.7	1	10	10.0
OTHER (INCLUDING JOINT)						
1993 & 1994	141	350	40.3	64	133	48.1
1988 & 1989	21	293	7.2	7	70	10.0
TOTAL						
1993 & 1994	960	2133	45.0	390	785	49.7
1988 & 1989	157	1786	8.8	54	410	13.2

TABLE 20

CURRENT STATUS OF PHD GRADUATES - BY MENTOR'S SUBFIELD
ALL YEARS COMBINED

SUBFIELD	POST DOC	TEMP	INDUS-TRY	GOVT	ACAD 4-YR	ACAD OTHR	OTHER U.S.	OUT CHEM U.S.	NOT EMP SEEKING	NOT EMP NOT SEEKING	RETURN TO C'NTRY	TOTAL NUMBER GRADS
As number												
BLANK (1)	268	24	358	43	114	8	10	19	58	5	51	959
ORGANIC	609	95	942	36	197	37	7	36	41	21	167	2172
INORGANIC	301	49	390	53	165	25	7	18	22	10	90	1128
ANALYTIC	159	55	572	59	107	12	7	8	19	8	64	1060
PHYSICAL	388	76	340	87	216	37	12	56	31	15	113	1367
BIOCHEM	193	19	130	24	82	18	5	20	6	4	35	511
THEORETIC	52	7	20	10	25	0	1	9	4	2	9	142
GENERAL	38	8	76	9	16	4	3	4	2	1	13	167
OTHER (2)	350	67	545	93	199	27	12	31	31	13	104	1450
ALL	2358	400	3373	414	1121	168	64	201	214	79	646	8956
As percentage of total for subfield												
BLANK (1)	27.9%	2.5%	37.3%	4.5%	11.9%	0.8%	1.0%	2.0%	6.0%	0.5%	5.3%	
ORGANIC	28.0%	4.4%	43.4%	1.7%	9.1%	1.7%	0.3%	1.7%	1.9%	1.0%	7.7%	
INORGANIC	26.7%	4.3%	34.6%	4.7%	14.6%	2.2%	0.6%	1.6%	2.0%	0.9%	8.0%	
ANALYTIC	15.0%	5.2%	54.0%	5.6%	10.1%	1.1%	0.7%	0.8%	1.8%	0.8%	6.0%	
PHYSICAL	28.4%	5.6%	24.9%	6.4%	15.8%	2.7%	0.9%	4.1%	2.3%	1.1%	8.3%	
BIOCHEM	37.8%	3.7%	25.4%	4.7%	16.0%	3.5%	1.0%	3.9%	1.2%	0.8%	6.8%	
THEORETIC	36.6%	4.9%	14.1%	7.0%	17.6%	0.0%	0.7%	6.3%	2.8%	1.4%	6.3%	
GENERAL	22.8%	4.8%	45.5%	5.4%	9.6%	2.4%	1.8%	2.4%	1.2%	0.6%	7.8%	
OTHER (2)	24.1%	4.6%	37.6%	6.4%	13.7%	1.9%	0.8%	2.1%	2.1%	0.9%	7.2%	
ALL	26.3%	4.5%	37.7%	4.6%	12.5%	1.9%	0.7%	2.2%	2.4%	0.9%	7.2%	

Notes: (1) BLANK indicates subfield was not reported.
(2) OTHER includes joint or combinations of subfields.

TABLE 21

OCCUPATIONS OUTSIDE CHEMISTRY FOR U.S. CITIZENS

Air Force		Insurance	
Airline Agent		Law School	8
Arms Control		Law/Attorney	11
Army		Library	
Ass. Dean		Materials	2
Astronaut		MBA	
Atmosp. Sci		Med School	6
Banking		Med/Arms	
Bus. Sch.		Med. Tech.	
Business	3	Med. Physic	
Cell Sci.		Medicine/Doctor	11
Comb. PhD		Military	
Comp. Prog/		Missionary	
Comp. Sci./		Molec. Bio	
Comp. Software/		Nat. Res.	
Computers	21	Navy	2
Compu. Bio		Not known	
Consulting	2	Nutrition	
Cook Pizza		Oceanogrph	
Coroner		Opera Sing	
Cust. Serv		Owns Pub	
Drugs		Patent Law/Office	8
Elec. Eng.		Pathology	
Electronic	4	Pharmacy	2
Engineer.		PhD Other	
Env. Engin		Pulp/Paper	2
Env. Educ.		Rad Physic	
Env. Contr.		Radiat. Med	
Export/Import	2	Radiology	2
Family Bus	3	Real Est.	
Fashions		Religion	2
Finance	3	Sales	2
Fireman		Spectrosc.	
High Tech	2	Stock Broker	
Industry		Teaching	
Instrument		USAF	

OCCUPATIONS OUTSIDE CHEMISTRY FOR TEMPORARY VISAS

Banking		Info Tech	
Biochem.		Law School	2
Bus. School		Materials	
Business		Molec. Bio	
Comput. Sci/Computer	8	Own Restr.	
Construct.		Patent Law	
Eng.		Physics	
Finance	2	Radiology	

TABLE 22

UNEMPLOYMENT RATE BY REGION FOR U.S. CITIZENS
ALL YEARS OF GRADUATION

	Number Seeking But Not Employed	Total Number From Region	Percent Unemployed
New England	9	710	1.3
Mid Atlantic	17	1036	1.6
S Atlantic	19	1069	1.8
E N Central	56	1454	3.9
E S Central	4	212	1.9
W N Central	6	470	1.3
W S Central	10	572	1.7
Mountain	8	531	1.5
Pacific	19	735	2.6
Total	148	6789	2.6

TABLE 23

U.S. CITIZENS IN POSTDOCTORAL POSITIONS BY REGION
COMPARING TWO MOST RECENT GRADUATION YEARS (1993 & 1994)
WITH TWO EARLIEST GRADUATION YEARS (1988 & 1989)

	1993 & 1994			1988 & 1989		
	Number of Postdocs	Total from Region	Postdoc Percent	Number of Postdocs	Total from Region	Postdoc Percent
New England	94	223	42.2	13	186	7.0
Mid Atlantic	152	320	47.5	25	262	9.5
S Atlantic	144	342	42.1	35	280	12.5
E N Central	194	454	42.7	23	363	6.3
E S Central	19	65	29.2	4	58	6.9
W N Central	66	154	42.9	18	120	15.0
W S Central	65	177	36.7	17	167	10.2
Mountain	90	161	55.9	8	151	5.3
Pacific	136	237	57.4	14	193	7.3
Total	960	2133	45.0	157	1780	8.8

ADDENDUM TO REPORT ON THE SURVEY OF DOCTORAL MENTORS
CONCERNING CURRENT EMPLOYMENT OF PHD GRADUATES

In the original report of May 15, 1995, we expressed concern over the effect of deriving the employment information through the mentors rather than directly from the PhD graduates. The report recommended that a sample of the graduates be surveyed as a check on the original survey. I have since learned that the ACS Salary Survey included questions that allow such a check.

Results of the 1995 Salary Survey will be reported separately. At this point, however, data relevant to the recent PhD graduates can be extracted to allow comparison with the earlier survey of the mentors. The first table shows the employment status of respondents who indicated that they were chemists earning their doctorates since 1988. Since the survey was directed only to ACS members in the U.S., the relevant group for comparison from the mentors' survey is those graduates in the U.S. That group is shown in the second table, and we focus on the percentage in postdoctoral positions.

The results from the two surveys are relatively close for the graduates of the first two years. However, in the "out years," the mentor's approximations of the percentage of graduates in postdocs remain about 5 percentage points above the levels reported by the graduates. The result is that the postdoc percentages from the mentors are more than double those from the graduates in the seventh year since the degree.

It must be realized that bias in the results from the Salary Survey is possible because only ACS members responded. On the other hand, the numbers of graduates covered by the two surveys are similar; e.g., there were 979 U.S graduates seven years out reported in the mentors' survey, and 924 comparably defined in the Salary Survey.

To see whether salary surveys of previous years showed any change in the postdoc percentages, the same data were drawn from the 1994 Salary Survey; these are presented in the third table. Since, in 1994, a sample was used instead of the universe of ACS members, the overall numbers of responding graduates are much smaller. Within the limitation of what can be said about small numbers without any statistical test, it appears that no significant shift has occurred between 1994 and 1995.

David C. Montgomery
June 28, 1995

Employment Status of Doctoral Graduates in Chemistry
from Years 1994 (1 year out) through 1988 (7 years out)
1995 ACS Salary Survey

	EMPLOYMENT STATUS										TOTAL	
	Full-time		Part-time		Postdoc		Seeking empl		Not seeking empl			%
		%		%		%		%		%		
Years since PhD												
1.00	335	44.7%	17	2.3%	346	46.2%	49	6.5%	2	.3%	749	100.0%
2.00	535	55.7%	15	1.6%	385	40.1%	22	2.3%	3	.3%	960	100.0%
3.00	673	72.8%	20	2.2%	208	22.5%	19	2.1%	5	.5%	925	100.0%
4.00	757	81.6%	18	1.9%	131	14.1%	21	2.3%	1	.1%	928	100.0%
5.00	828	84.7%	26	2.7%	88	9.0%	30	3.1%	5	.5%	977	100.0%
6.00	883	88.7%	31	3.1%	57	5.7%	17	1.7%	7	.7%	995	100.0%
7.00	846	91.6%	16	1.7%	37	4.0%	22	2.4%	3	.3%	924	100.0%
TOTAL	4857	75.2%	143	2.2%	1252	19.4%	180	2.8%	26	.4%	6458	100.0%

SUMMARY OF RESULTS OF 1995 SURVEY OF DOCTORAL MENTORS
INCLUDING ONLY THOSE PHD GRADUATES IN THE U.S.

YEAR OF GRADUATION	TOTAL GRADS	OUTSIDE U.S.	POST-DOC	POSTDOCS AS % OF TOTAL IN U.S.
94	1480	69	749	53.1%
93	1438	74	601	44.1%
92	1312	113	392	32.7%
91	1299	102	245	20.5%
90	1231	106	160	14.2%
89	1132	97	114	11.0%
88	1064	85	97	9.9%
TOTAL	8956	646	2358	28.4%

DCM:6/28/95

Employment Status of Doctoral Graduates in Chemistry
from Years 1993 (1 year out) through 1987 (7 years out)
1994 ACS Salary Survey

	EMPLOYMENT STATUS										TOTAL	
	Full-time		Part-time		Postdoc		Seeking empl		Not seeking empl			%
		%		%		%		%		%		
Years since PhD												
1.00	70	58.8%	2	1.7%	42	35.3%	5	4.2%	0	.0%	119	100.0%
2.00	88	50.9%	4	2.3%	78	45.1%	1	.6%	2	1.2%	173	100.0%
3.00	132	70.2%	2	1.1%	50	26.6%	4	2.1%	0	.0%	188	100.0%
4.00	148	82.2%	2	1.1%	25	13.9%	4	2.2%	1	.6%	180	100.0%
5.00	164	89.1%	3	1.6%	14	7.6%	2	1.1%	1	.5%	184	100.0%
6.00	167	90.3%	1	.5%	11	5.9%	6	3.2%	0	.0%	185	100.0%
7.00	167	89.8%	2	1.1%	8	4.3%	8	4.3%	1	.5%	186	100.0%
TOTAL	936	77.0%	16	1.3%	228	18.8%	30	2.5%	5	.4%	1215	100.0%

INDIANA UNIVERSITY

RESEARCH AND
THE UNIVERSITY
GRADUATE SCHOOL

August 14, 1995

The Honorable Steven Schiff
Chairman
Subcommittee on Basic Research
Committee on Science
U.S. House of Representatives
Rayburn House Office Building Suite 2320
Washington, DC 20515-6301

Dear Mr. Chairman:

Attached please find responses to the questions posed in your letter of July 28, 1995.

I appreciated the opportunity to testify before your committee on July 13, 1995. The thoughtfulness and courtesy of your subcommittee were much appreciated, and the open, frank exchange of views during the hearing was enlightening. I hope the other participants were similarly impressed.

I thank you for the efforts this hearing has produced and hope that my participation will help the committee in its future deliberations.

Sincerely,

George E. Walker
Vice President for Research
and Dean of the Graduate School
Chair, Board of Directors
Council of Graduate Schools

Enclosure

OFFICE OF THE
VICE PRESIDENT AND DEAN

Bryan Hall 104
Bloomington, Indiana
47405-1201

812-855-8913
Fax: 812-855-2205

Questions for Dr. Walker

1) *The COSEPUP report found, and nearly all the witnesses at the hearing concurred, that there is insufficient relevant and timely career data available to students, prospective students, and faculty advisors. This lack of information impedes the ability of graduates to make informed choices about their careers. What should the federal government's role be in ensuring that this type of information is available and up to date?*

The federal government has a continuing role and responsibility in facilitating the tracking of Ph.D. graduates in all fields important to the national interest. Science and Engineering have been on this list since World War II, but other national goals, including the space program, national defense, and economic competitiveness have expanded the list to include virtually every field in which a Ph.D. is available. As a practical matter, it is easier to gather data on all Ph.D. graduates and then break out detailed information than to limit data gathering to science and engineering fields.

The National Science Foundation has been a federal lead agency both in providing support and coordinating support from other federal agencies to develop federal partnerships to collect and analyze information gathered from individual institutions. This role, and funding for it, needs to be continued and enhanced, as the COSEPUP report and our testimony suggest. Enhancement to improve the quality of information and timeliness will require additional resources. Some improvement in timeliness and availability can be expected from the NSF's user-friendly technology, but other federal agencies need to be encouraged to support and expand the NSF's example. Current budget reductions are likely to have the opposite effect, with data and outreach efforts already suffering cutbacks because of limited budgets. The most recent published data from the NSF is for 1993, and for most other agencies, 1992.

Apparently no other government agency is as interested or as effective as the NSF in doing this job. Therefore, the committee should look for ways to support and enhance the NSF's role: corporations and non-governmental support should also be encouraged.

Should data collection and analysis be undertaken by the professional societies with university participation? Or, should this responsibility be undertaken by a partnership between government, professional societies, and universities? Describe the optimum partnership.

Government, professional societies, and universities are all involved in data collection. The optimum partnership should grow from current successful arrangements. Universities should be encouraged to enhance tracking of selected Ph.D. fields by building on existing data collection efforts supported by the NSF. Professional and disciplinary associations should also be encouraged to survey and make available employment and salary data within a short time-fame to measure the market in field-sensitive ways. University and professional associations should collaborate in funding research on recent graduates and post-docs. The first several post-Ph.D. years are perhaps the most fruitful time in the career of a scientist. We need to know more about jobs and research productivity of Ph.D. recipients in the first decade after they receive their degrees. Current samples of these populations should be increased both in size and frequency.

Regular meetings to encourage collaboration among data-gathering groups should be encouraged. Those professionals from agencies with data responsibilities should share strategies and resources. These federal groups should, in turn, share strategies and funding with professional discipline associations, scientific societies, groups such as the National Research Council, and private foundations, to ensure that data is gathered efficiently and published widely in a timely manner.

Should federal research grants be predicated on a requirement that doctoral granting universities track their graduates for a period of 10 years following receipt of degree?

Federal research grants should not require tracking of graduates. A ten-year tracking requirement would needlessly complicate existing arrangements. I believe that market, campus, and alumni relationships are sufficient to drive increased interest and tracking of

graduates and non-graduates. Providing funding for research on tracking by various cooperating groups would produce more and better data than new regulations.

2) *Would time to degree be reduced by a policy which restricts federal support to those schools which have a stated, enforced policy on time to degree?*

What would be the effect of this type of policy on graduate education and/or research projects.

As stated in our previous testimony, most institutions have and enforce a policy on time to degree. I believe restricting federal support would not improve time to degree in actual practice. Such a policy would add more complicating requirements to an already challenging process. Good clear definitions of time to degree and how to accurately measure it would be useful, and could be developed via the consultation process with interested, cooperating parties as discussed in the response to question one.

3) *How can universities attract more women and minorities into science and engineering degree programs?*

Maintain, sustain and expand support for women and minorities through programs that are funded consistently over long periods of time. These programs should begin in the elementary grades and extend support through post-doctoral awards. The latter programs should be in connection with ongoing research programs that provide incentives for successful Ph.D. completion. Thus, they would reward and expand successful programs. Recognition and financial rewards for those who improve access and expand the pool of qualified minorities and women in selected fields would be helpful (e.g., providing financial awards for successful, inspiring teachers at all levels of education). Expanded summer research internships for students at multiple career stages would also help. Long-term, sustained funding will be key for the payoff in increased numbers of minorities and women. These must be maintained for decades to have an effect.

National, state and institutional leadership are also required to emphasize how important good science is to the nation's future, and how important it is for all citizens to participate in some way in its teaching, learning and development.

American Chemical Society

OFFICE OF THE PRESIDENT

1155 SIXTEENTH STREET, N.W.
WASHINGTON, D.C. 20036
Phone (202) 872-4600

Ned D. Heindel
President-Elect, 1993
President, 1994
Immediate Past President, 1995

August 21, 1995

The Honorable Steven H. Schiff
Chairman
Subcommittee on Basic Research
Committee on Science
2320 Rayburn House Office Building
U.S. House of Representatives
Washington, DC 20515-6301

Dear Mr. Chairman:

Thank you once again for the opportunity to testify before your Subcommittee on the critically important issue of graduate education in the sciences and engineering. What follows is a response to the three questions outlined in your letter dated July 28, 1995.

(1) ***What should be the federal government's role be in fostering the tracking of Ph.D. graduates, and ensuring that this type of information is available and up to date?***

On a biannual basis, the National Science Foundation (NSF) publishes an extensive report, "***Science and Engineering Indicators.***" The report analyzes data on the number and type of science and engineering degrees earned by undergraduates, masters and doctoral students. It also includes an analysis of the relevant employment sectors, along with a forecast of future employment needs. These biannual reports are of great value to the scientific and engineering community. Never-the-less, they do suffer from a lack of timeliness. Unfortunately, this situation is inherent to the process rather than any shortcoming of it. These type of surveys are difficult to conduct and analyze in a timely manner. Because of their value, the federal government should continue to support these activities and ensure that adequate budgets are available to conduct these vital activities.

Should data collection and analysis be undertaken by professional societies with university participation? Or, should this responsibility be undertaken by a partnership between government, professional societies, and universities? Describe the optimum partnership.

Data collection relevant to employment and degree awards are already underway by many professional societies, ACS included. Naturally, those societies represent specific scientific and/or engineering disciplines and will have a data set unique to their needs and concerns. What could occur, though, is better integration of the different data sets collected by the federal government and the various professional societies, through such organization as the American Association for the Advancement of Science. Integration could provide a more comprehensive overview of the Nation's S&E base. However, such a process is not trivial because of inconsistent databases and the type of questions asked on the surveys. The federal government's involvement would not necessarily eliminate these problems.

(2) ***Would time to degree be reduced by a policy which restricts federal support to those schools which have a stated, enforced policy on time to degree?***

Time to degree would be reduced by such a policy. However, caution must be exercised when establishing timelines and enforcement policies. Illness, maternity leave, absences for family emergencies, and spousal relocations can interfere with a specific student's expeditious completion of his/her advanced degree. Further, the time necessary to earn an advanced degree in different disciplines can not be standardized. Sufficient flexibility must be built in to the process to allow schools and disciplines to establish appropriate guidelines as well as to allow for the extraordinary cases.

As a part of a time to degree policy, an accountability analysis could be instituted. Such analysis could be accomplished through an appendix to each proposal, similar to the affirmative action statements presently required. Therein, the applicant institution would have to quantify its performance in time to degree within a specific subject area or research component (academic department or center) from which the application is arising.

What would be the effect of this type of policy on graduate education and/or research projects?

Provided flexibility as described above is built in to a policy, no adverse effects should result.

(3) ***What is the best mix of graduate research assistanships, traineeships, and fellowships for support of graduate students in science and engineering?***

The best mix can not be determined *a priori.* In addition, the mix that may be appropriate for one discipline may not be optimal for another. A "one-size-fits-all" approach is not possible. Each discipline needs to be given the ability to explore different mixes and approaches to supporting graduate education and research.

At present, the physical sciences rely more heavily on research assistantships, while the biomedical community makes greater use of traineeships. In each case, improvements are possible. It is clear that the former community should shift somewhat more towards traineeships and fellowships. Federal agencies should be encouraged and enabled to implement new mechanisms of student support, consistent with the needs of the students in the particular research community. Specific measurements and performance milestones should be developed in advance. so that positive or negative results can be monitored and learned from.

I hope these responses are helpful to you as you consider the future of graduate education in the sciences and engineering. The American Chemical Society would be pleased to offer you additional assistance in this area should the need arise.

Sincerely yours,

Ned. D. Heindel

Kevin D. Aylesworth
825 Quince Orchard Blvd., #21
Gaithersburg, MD 20878
(301) 527-1677
kda@ix.netcom.com

August 18, 1995

Hon. Steven H. Schiff
Chairman, Subcommittee on Basic Research
U.S. House of Representatives
VIA FAX (202) 225-7815

Dear Representative Schiff,

Thank you for asking me to testify at the July 13, 1995 hearing on the COSEPUP report. The issues raised in the report and in the testimony at the hearing are critical for determining a coherent science policy for the future. A future that will bear little resemblance to the recent past.

My answers to your follow-up questions follow. If I can be of assistance in any way in the future, please don't hesitate to call.

Sincerely,

Kevin Aylesworth

Kevin Aylesworth

Dr. Kevin D. Aylesworth: Response to follow-up questions.

Question 1: The COSEPUP report found, and nearly all witnesses at the hearing concurred, that there is insufficient relevant and timely career data available to students, prospective students, and faculty advisors. This lack of information impedes the ability of graduates to make informed choices about their careers. What should the federal government's role be in fostering the tracking of PhD graduates, and in ensuring that this type of information is available and up to date?

Should data collection and analysis be undertaken by the professional societies with university participation? Or, should this responsibility be undertaken by a partnership between government, professional societies, and universities? Describe the optimum partnership.

Answer: The federal government should coordinate the data collection and analysis functions of government agencies, universities and professional societies. To avoid conflicts of interest, the coordinating agency should not also be responsible for training scientists. The money for this agency (perhaps one to two million dollars) would have to come from the current research budget.

Undoubtedly, the research community would resist this shift of funds. One answer to the anticipated objections is that there are two products of the federally funded research system: research and students. To determine whether federal funds are being wisely spent, we need to know the fates of the students who receive federal funds. This can only be done by coordinating the data collection efforts of the existing agencies and professional societies.

Question 2. Would time to degree be reduced by a policy which restricts federal support to those schools which have a stated, enforced policy on time to degree?

What would be the effect of this type of policy on graduate education and/or research projects?

Answer: Time to degree would probably be reduced by a policy that restricts federal support to schools that have a stated, enforced policy on time to degree. Although this would get the students out faster, it might not have much effect on the ultimate fate of the students. One response of the system will be to tack more years onto postdoctoral positions. Something must also be done to reduce the time spent in postdoctoral appointments.

Question 3. In your testimony you mention that research assistantships are very confining for graduate students. Should the federal funding agencies do away with research assistantships altogether? If not, what would be the right mix of research assistantships, traineeships, and fellowships?

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Answer: Ultimately, the power structure of graduate education must change if we expect U.S. citizens to continue to pursue PhDs in science. To do this, money for graduate assistantships needs to be shifted from individual research grants to block grants to institutions and fellowships directly to the students.

This shift should occur over a ten-year period to give the system a chance to adjust. A target distribution would be one third of the funds in each channel (fellowships, block grants, and research grants). The results of this shift on the students and research productivity should be monitored. The amounts could then be adjusted to accomplish various policy goals.

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